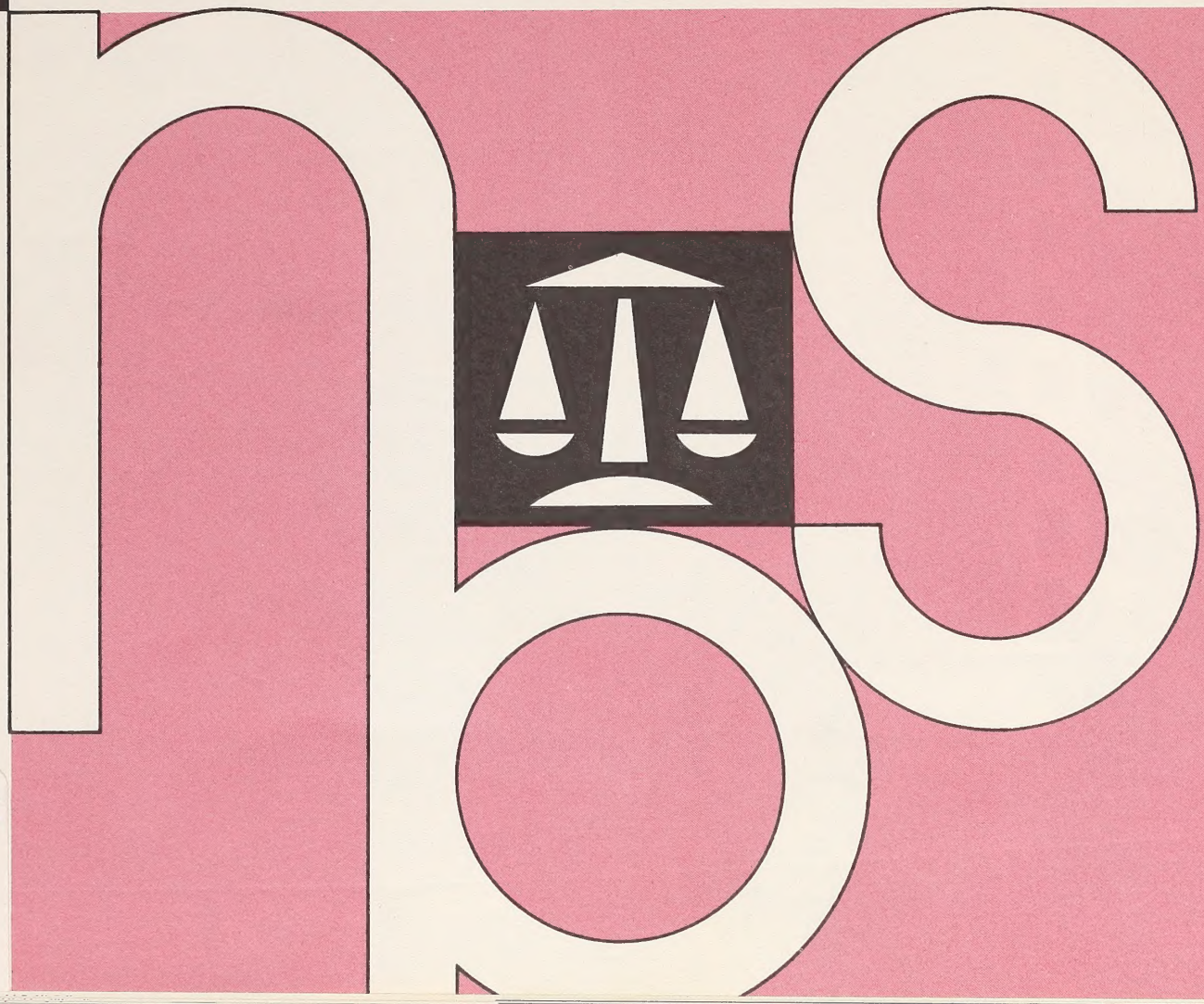
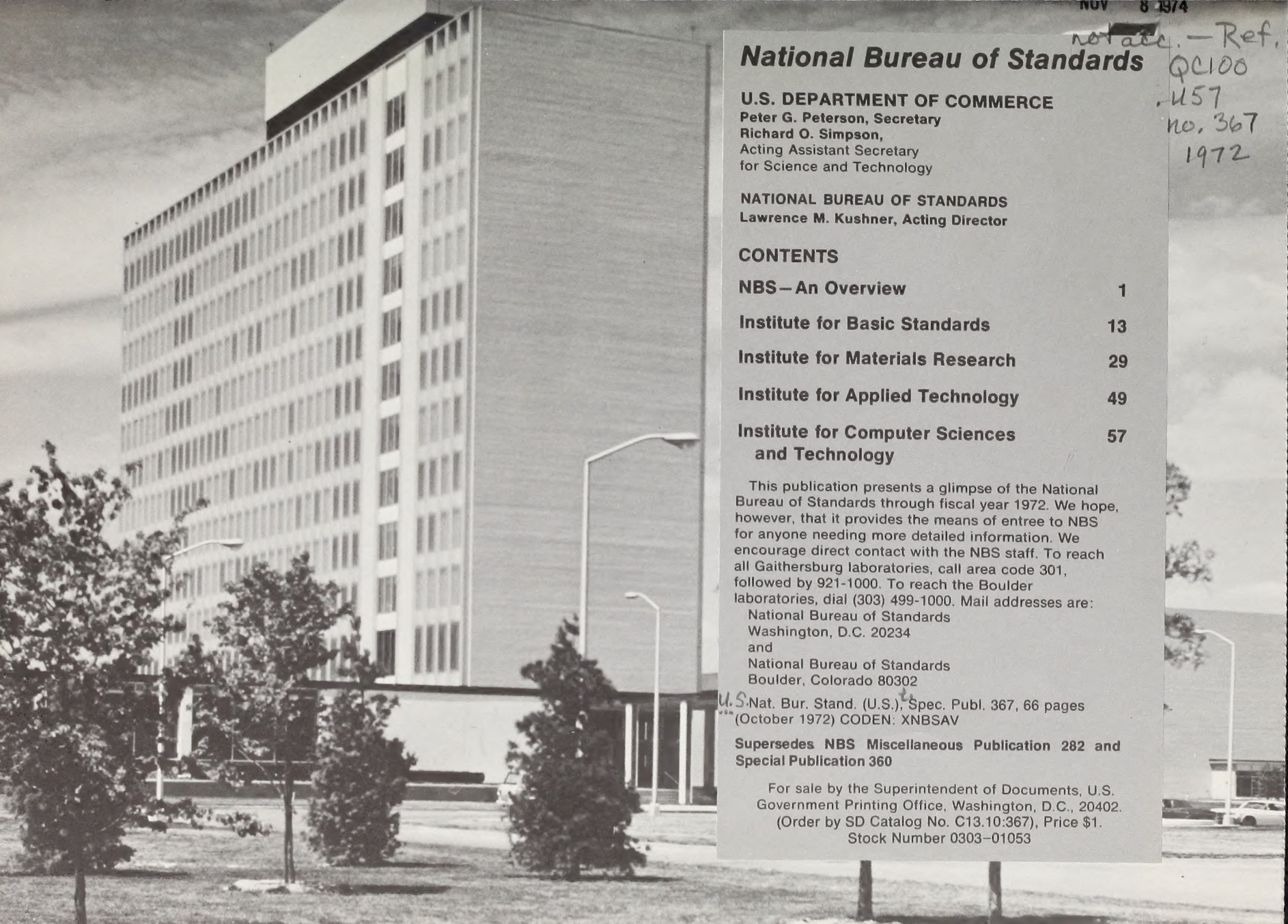
A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

NATIONAL BUREAU OF STANDARDS





National Bureau of Standards

U.S. DEPARTMENT OF COMMERCE
Peter G. Peterson, Secretary
Richard O. Simpson,
Acting Assistant Secretary
for Science and Technology

NATIONAL BUREAU OF STANDARDS
Lawrence M. Kushner, Acting Director

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This publication presents a glimpse of the National Bureau of Standards through fiscal year 1972. We hope, however, that it provides the means of entree to NBS for anyone needing more detailed information. We encourage direct contact with the NBS staff. To reach all Gaithersburg laboratories, call area code 301, followed by 921-1000. To reach the Boulder laboratories, dial (303) 499-1000. Mail addresses are:

National Bureau of Standards
Washington, D.C. 20234
and
National Bureau of Standards
Boulder, Colorado 80302

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NBS—AN OVERVIEW

THE National Bureau of Standards was created by Congress in 1901 to meet the needs of a growing Nation for a unified measurement system. For more than 70 years the Bureau has contributed to advances in science and technology, the growth of industry, and efficiency of the marketplace. In so doing, the Bureau has built a scientific facility and staff that stands with the world's best.

The basic enabling legislation of 1901, as amended, establishes the main purposes and functions of the Bureau as follows:

- the custody, maintenance and development of the national standards of measurement, and the provision of means and methods for making measurements consistent with those standards including the comparison of standards;

- the determination of physical constants and properties of materials . . . of great importance to scientific or manufacturing interests . . . not to be obtained of sufficient accuracy elsewhere;

- the development of methods for testing materials, mechanisms, and structures and the testing of materials, supplies, and equipment . . .;

- cooperation with other Government agencies and with private organizations in the establishment of standard practices, incorporated in codes and specifications;

- advisory service to Government agencies on scientific and technical problems;

- invention and development of devices to serve special needs of the Government.

Thus, NBS has both unique and special responsibilties in relation to the Nation's science and technology, and very broad responsibilities as well.

Our cornerstone responsibility is to serve, for the United States, as the authoritative source of accurate, compatible, and useful physical measurements and further to ensure their international compatibility. No nation in the modern world, much less the world's leading scientific and technological society, can prosper and function effectively if the national system of measurement is in a state of anarchy. A nation cannot have two sizes for the inch, two weights for the pound, or two values for the units describing electric power, temperature, frequency, time, or any of the 40 or more derived measurement quantities and their many useful combinations.

Only one laboratory can speak for the Nation in the international community of metrologists who work together under the aegis of the Treaty of the Meter to produce a single, compatible world system of measurement units. This laboratory must be beyond question in its integrity and competence. It must be devoted entirely to objective technical truth for it must be able to resolve conflicts when two people—or two companies—measure the same thing and get different answers. These principles provide the modus vivendi of the National Bureau of Standards and are strongly and deeply felt by each of our professional staff members.

NBS GOAL

To advance the Nation's science and technology and to promote their effective application for public benefit

NBS PROVIDES

- *Measurement Services for Science and Technology*
- *Science and Technology for Industry and Government*
- *Technical Services for Equity in Trade*
- *Technical Services for Public Safety*
- *Technical Information Services*

MEASURES FOR THE MARKETPLACE

If a free-enterprise economic system is to thrive in a modern industrial society, indeed if it is to survive, buyers and sellers in the marketplace need to have as much confidence in the quantity and performance of goods exchanged as they do in the amount of monies paid. A substantial part of the Bureau's measurement research is devoted to the development of fair, objective, and useful measurement methods for application to both durable and nondurable goods in trade.

The commercial life of this country depends upon the Bureau's services because both buyer and seller need an unbiased, honest third party with the technical capability to say "this measurement is fair and accurate; that one is not." The Bureau of Standards provides this third-party independence and integrity.

A FLEXIBLE PROGRAM

This laboratory, with a 70-year tradition of scientific excellence and integrity, finds itself not only in great demand but also acquiring additional major responsibilities that go far beyond the specific research requirements for the national system of measurement. As the decades have passed, the Bureau has responded to the country's problems as they arose, in war and in peace, in times of rapid scientific growth, in times of scientific retrenchment and serious domestic problems. Throughout the thousands of useful projects at NBS runs a common thread: the Bureau helps others with applied research services to produce, diffuse, and enhance the value of practical knowledge. Our goal is to advance the Nation's science and technology and to promote their effective application for public benefit. In short, to help make science useful and technology the servant and not the master of people. The Bureau's mission is sufficiently broad to allow the Bureau to respond to changing needs. Such a freedom of choice demands a continual appraisal of the mesh between NBS services and national needs.

One of the most exciting new programs of the Bureau is a Presidential initiative to help improve our understanding of the process of innovation and application of research. The Experimental Technology Incentives Program (ETIP) will investigate ways to stimulate R&D investments and applications by private firms and non-Federal institutions. ETIP was begun in 1972 in conjunction with the National Science Foundation to involve the Federal Government, private sector organization and local and State governmental entities in an effort to improve the environment for innovation, development, and marketing of new products or methods. The program is intended to promote American industry's exploitation of science and technology for the public good and to strengthen the American economy.

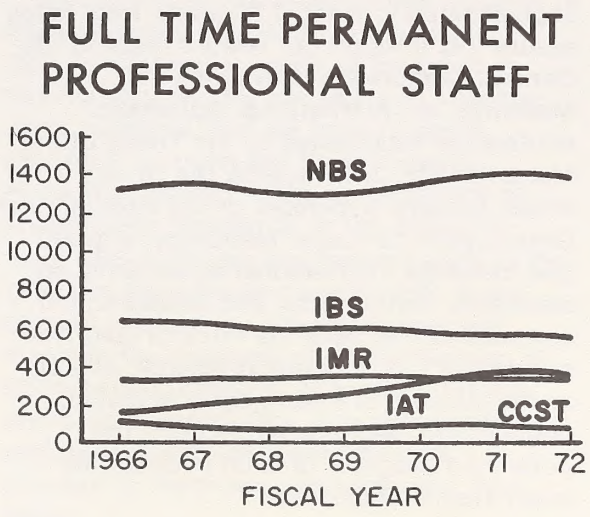
PUBLIC PROTECTION

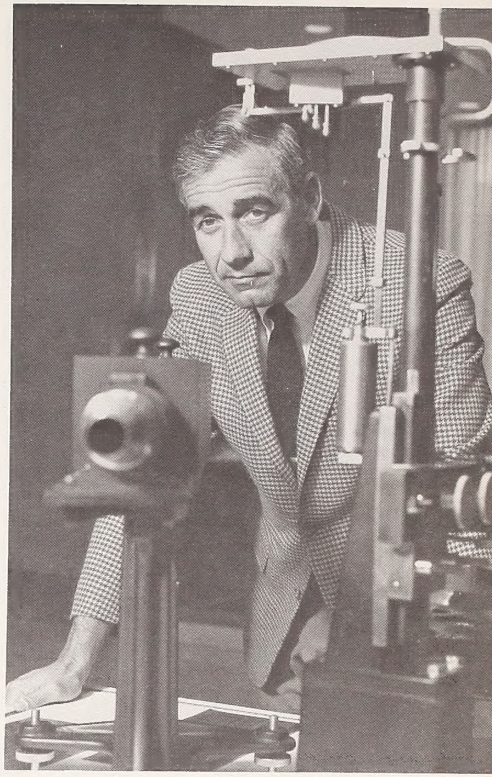
Today, the Bureau serves a wide variety of government agencies and works closely with private trade associations, organizations, and professional societies to develop the technical base and standards for many important programs. Bureau personnel are involved in consumer protection, ranging from the development of mandatory standards to protect against injury or death from flammable fabrics to voluntary product safety standards for toys, household, yard, and industrial equipment. The Bureau also develops standard weights and measures which the States and local governments use to protect the consumer. The Bureau conducts research in environmental control, including air and water pollution, noise abatement, and radiation safety. Programs in health and safety include the development of clinical standard reference materials, analysis of the reason for failure of prosthetic devices, automobile parts, bridges and buildings, pipelines, and other products. Other NBS programs in this area include dental research, mine safety, and lead paint poisoning control. Bureau scientists also conduct studies in fire protection and law enforcement, building design and materials construction, energy production and transmission, and computer science and technology.

AN OTHER AGENCY RESOURCE

Thirty-eight percent of all the funds expended by NBS are transferred to it from other government agencies in reimbursement for technical and research services. These services range from brief consulting tasks, often offered without reimbursement, to special tasks of days or weeks duration, all the way to formal continuing agreements to provide very substantial technical support to another department of government to aid in their decision making.

In years past, certain programs for other agencies reached such a level that an entire activity became self-sustaining and was transferred out of the Bureau. The largest example was the transfer of 1,500 employees to the Army Ordnance Corps to create the Harry Diamond Laboratories in 1953, followed closely by the transfer of 400 employees in 1954 to the Navy to create the Naval Ordnance Laboratory at Corona, Calif. An organizational change within the





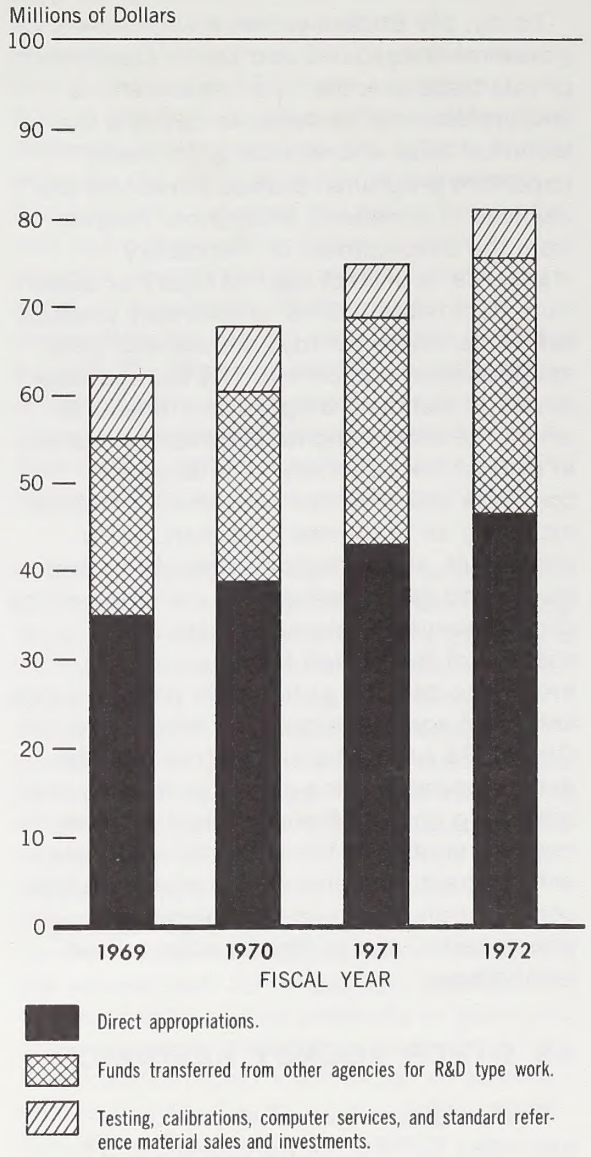
Dr. Lawrence M. Kushner, NBS Acting Director, examines a new display in the NBS Museum.

Department of Commerce in 1965 transferred more than 500 employees of our Central Radio Propagation Laboratory at Boulder to the then newly formed Environmental Science Services Administration. In 1968 a small group of 20 employees were transferred to the General Services Administration to create the Materials Evaluation Laboratory. The 50-man Office of Vehicle Systems Research was transferred to the Department of Transportation in July 1971.

INTERNATIONAL

As the world's leading technological nation the United States has a vital interest in ensuring that the world system of measurement is not only internationally compatible but is also sufficiently sophisticated to meet U.S. needs. NBS helps assure this through our relationships to the General Conference of Weights and Measures, an international diplomatic conference established by the Treaty of the Meter in 1875. Just recently the United States became a member of the International Organization for Legal Metrology, a group that develops international agreements on standards, instruments, and measurement procedures that have the force of law. The success of U.S. foreign commerce, as well as the success of international scientific cooperation, depends partly upon the continued progress of such cooperative international endeavors.

TOTAL OPERATING BUDGET



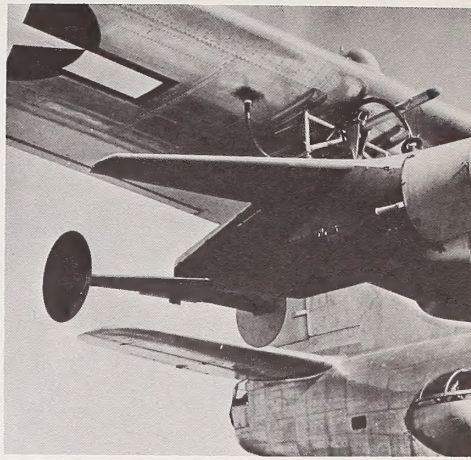
A METRIC AMERICA?

As guardian of the Nation's basic measurement system, the Bureau was asked by Congress to evaluate the need and feasibility of bringing the metric system into everyday use in the United States. A Metric America, the report of the U.S. Metric Study, was transmitted to the Congress on July 30, 1971. In February 1972 Secretary of Commerce Peter G. Peterson sent to Congress proposed legislation which would initiate a planned, but voluntary, coordinated changeover to take place over a 10-year period. The Bureau's Metric Group is working with industry and many government and private organizations to produce information which will help ease the impact of this gradual process of metrication.

ENGINEERING STANDARDS

The existence of a satisfactory set of engineering standards and a satisfactory mechanism of generating them can do a great deal to assure that a country's use of technology in its commercial products and industrial processes lives up to its full potential yet does not do violence to the public interest. A healthy and effective national standards program can promote innovation and improve productivity in industry, and can provide the small businessman with a better opportunity to break into an established market or to bid on components and materials subcontracts. It can save millions of dollars in the writing of technical specifications for competitive bids and can improve the standards of industrial practice throughout our Nation. Since the standardization system in the U.S. is voluntary, and strives for a concensus, it is sometimes disappointingly slow and may occasionally even operate to impede commerce or competition. There is frequently a need for public interest representation at the standards negotiating table. The standard-setting system is uneven in its technical quality and suffers from the lack of both financial and scientific support from both industry and government. But without the efforts of more than 100,000 working engineers and scientists to continually update the tens of thousands of standards prepared by a host of organizations, we would either have to revert to a pre-industrial society, or establish the standards by decree as they do in many countries.

NBS works on the development of some of the mandatory standards which the Government issues, such as for fabric flammability and for the safety of toys and other products, and we have research programs to assist the Environmental Protection Agency in the development of antipollution standards. In the computer field, NBS develops and recommends to the Office of Management and Budget those Federal Information Standards that will increase the economy and effectiveness of Government computer utilization through improved compatibility, interchangeability, and performance of automatic data processing hardware, software, and data bases.



The Bureau helped develop the Bat, the first guided missile ever used in combat. It was unpowered, gliding from the release plane to the target.

NBS efforts to develop the scientific and engineering basis for performance-based building standards could permit a more rapid rate of innovation in the building industry. However, development of these many thousands of standards reside in the private sector. They are developed voluntarily, and their use is usually voluntary.

The development of engineering standards is done in committees on which representatives of manufacturers, producers, distributors, and users are normally represented. By and large, the members of these committees are technical people.

Approximately 350 members of the technical staff of the National Bureau of Standards serve on some 950 standardization committees sponsored by private standards-writing organizations. Their service on these committees is part time and only rarely becomes a large fraction of their total activity. Bureau people hold 129 committee officerships. Such participation is an important and desirable way for the technical expertise of the NBS to be reflected in industrial practice.

NBS participation is not, however, restricted to technical considerations; there is substantial representation in the major standardization bodies at the policy-making

In lending technical assistance to the Food and Drug Administration in the area of toy safety, NBS has studied the susceptibility of clacker-balls to fracture or shatter under impact. Here 5-year-old Paul Calvano demonstrates their operation with a safe pair of clacker-balls.

level. For instance, the Director of the National Bureau of Standards is, by virtue of his office, on the Board of Directors of the American National Standards Institute. An NBS staff member is also on the Board of Directors of the American Society for Testing and Materials.

NBS also operates an Engineering Standards Information Center which provides an information service on standards. Each year, it handles upwards of 5,000 inquiries from the public and from other Government agencies on the availability and source of national, international, foreign national, industry, State and Federal Government standards. The Center maintains a library of more than 85,000 standards and publishes general and specialized indexes of standards. These indexes allow one to quickly identify the title, identification number, publishing organization, and the year of publication of each standard. The standards themselves are usually copyrighted by the issuing organization which offers them for sale.

In addition, the Department of Commerce, through the National Bureau of Standards, operates a program called the Voluntary Product Standards Program. Through this program private groups can develop voluntary engineering standards which the private-sector standardization organizations are unwilling or unable to generate. NBS administers a set of consensus procedures (Part 10 of Title 15, Code of Federal Regulations) providing for input from all of the important groups concerned with the proposed standard. The Bureau is now reorienting the program so as to supplement the ability of the private-sector organizations to generate voluntary standards in areas of particular concern to the Government—most immediately in the field of product safety.

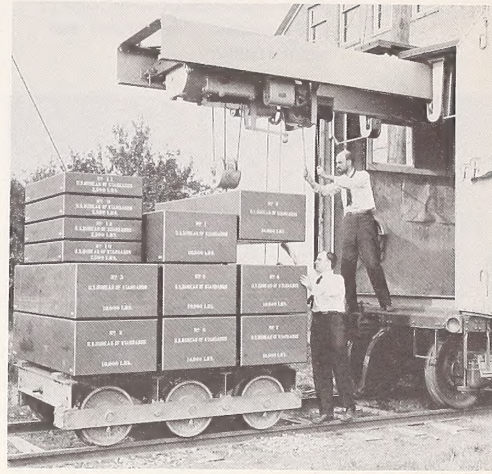
FACTS AND FIGURES

In order to meet growing national needs, the Bureau has been steadily developing its two most important assets—staff and facilities.

The Bureau's principal facilities are located at Gaithersburg, Md., and Boulder, Colo. On the 576-acre Gaithersburg site are 23 buildings containing 1,200,000 square feet of working area. NBS required a large site because many of our measurements require maximum isolation from such interference as noise, vibration, and electromagnetic radiation; and one of the best means of ensuring isolation is to provide distance between the experiment and interference sources.

The second major facility at Boulder, Colo., carries on such work as cryogenics, electromagnetic measurements, time and frequency standards, and quantum electronics. The Boulder site consists of 205 acres, 14 buildings, and 302,000 assignable square feet of floor space. At Boulder we also occupy and staff jointly with the University of Colorado the Joint Institute for Laboratory Astrophysics, which was established in 1962 to bring the Bureau's measurement expertise in atomic physics to bear on some problems of astrophysics and atmospheric physics.

This test car was sent around the Nation calibrating railway track scales, some of which were grossly inaccurate. A similar car is still in service.



In addition, the Bureau has a 380-acre field station at Fort Collins, Colo., for Standard Frequency and Time Interval Broadcast Stations WWV, WWVB, and our experimental station WWVL. Transmitting facilities for WWVH were recently completed on the Island of Kauai in the Hawaiian Islands. NBS also has a Master Railway Scale Facility at Clearing, Ill.

The work of the Bureau is carried out by a total staff of nearly 3,800 employees. Eighty-three percent of the staff is at Gaithersburg, Md., and 17 percent is at Boulder, Colo.

The staff comprises some 44 percent scientists and engineers, 14 percent technicians, and 42 percent administrative and support personnel. The scientific and engineering staff consists of 34 percent physicists, 20 percent chemists, 23 percent engineers, 5 percent mathematicians, and 18 percent others. Thirty-six percent of our scientists and engineers have Ph.D. degrees.

In addition, there are normally about 60 Research Associates and Guest Workers engaged in projects at the Bureau.

These automobiles were used in 1927 studies of headlights and night visibility.

INFORMATION EXCHANGE

Information is a product of all the activities at the National Bureau of Standards. Communication of information is a two-way process; it includes the outward transmission to the public of information produced at NBS and the inward transmission to NBS of information about new developments in industry and in universities, newly appearing needs of society, and new opportunities for NBS.

Members of the NBS staff give formal talks, write papers, consult on the telephone with callers, write letters, and discuss technical problems with visitors. They publish papers in technical journals and in the public press. Approximately 30 major conferences and a few hundred seminars are held at NBS each year. NBS operates more than 30 specialized information centers, and organizes precision-measurement seminars and training courses.

Research staff members are often consulted by colleagues in industry, universities, and other government laboratories. These interactions are an important part of our communication process and the NBS staff is strongly encouraged to develop close relationships with colleagues in many laboratories. Such consultation is by no means a diversion from our primary tasks; it is an essential element of a continuing responsiveness to the needs of society.

In other ways, too, NBS works with American industry and with universities in exchanging information. Two of the formal programs are the Industrial Research Associate Program and the Postdoctoral Research Associate Program. The industrial program brings researchers from industry to the NBS campus to conduct research on problems of mutual interest to both NBS and

the sponsoring industry or trade association. The Postdoctoral program offers new or recent graduates the opportunity to work on major problems at NBS for a year or two. This is a competitive program and is operated in cooperation with the National Research Council, National Academy of Sciences-National Academy of Engineering.

The three basic principles guiding the NBS information program are: (1) Quality of information—that is, its reliability and credibility—is more important than access to great masses of unevaluated information; (2) Information must be appropriately packaged and interpreted for each community of users; (3) A variety of information from many sources is needed for decision makers at all levels throughout society. NBS also has a responsibility to help the user apply the information to his problems. In the fire research program, for example, good information properly interpreted by NBS will not reduce losses of life and property due to fires; the information must be applied to real conditions in order to have an impact. Making sure that it has that impact is part of NBS responsibility too. NBS works with professional associations, Federal, State, and local officials, and industry representatives to assure that potentially useful information is put to work.

Information is collected, processed, interpreted, analyzed, and disseminated for use by the entire community of scientists and engineers. Our largest program of this type is the National Standard Reference Data System (NSRDS). It comprises a network of more than 2-dozen information analysis centers at NBS and other laboratories, plus other related activities, all producing critical reviews and compilations of critically evaluated data. The scope is not just one specialized area of technical information but the entire broad field of physical and chemical properties of substances. NBS does not work alone in this major effort. Under the terms of the 1963 Federal Policy Statement and the 1968 Standard Reference Data Act (P.L.90-396) NBS coordinates a program which includes the work of all Federal agencies, and calls upon the Nation's professional societies and individual scientists and engineers as well.

Broad as the present scope of the NSRDS is, it does not encompass all the types of data needed by engineers and scientists. Data such as the tensile strength of steel, the melting point of a plastic, or the reflectivity of a paint will receive increasing attention in the future.

Continued data evaluation proves useful to the solution of a wide variety of problems. An example is a project undertaken at the request of the American Society of Mechanical Engineers, whose objective was to compile data on heats of combustion which could be incorporated into a handbook for designers and operators of waste incinerators. The resources of the NBS Thermochemical Data Center, which has been actively compiling thermochemical and thermodynamic data for more than 20 years, permitted the NBS to turn to this special field and assemble the needed data in a rapid and efficient manner.

NBS has long been a meeting place for a wide variety of scientific groups. This is the International Technical Committee of 1910, gathered at the Bureau to establish new values for the ampere, ohm, and volt. Director Stratton is sixth from the left.

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TOWARD TOMORROW

In 1901, when NBS was created, the population of this Nation was about 80 million people. Telephones, automobiles, radios, and electric lights were rarities; the airplane but a dream.

Today our population is over 200 million, with 74 percent concentrated in urban areas. Superhighways and jet routes crisscross our land and sky, the 25-year-old computer industry is the eighth largest in the country, and we are headed toward what many call the post-industrial society.

Has NBS, formed to meet the needs of a less complex time, kept pace with such tremendous change? In those areas that are as relevant today as they were many years ago, NBS has responded by constantly upgrading its measurement capabilities. Take time measurements as an example. In the 1920's the Bureau was using a pendulum clock as its standard, achieving an accuracy of one part in 10^5. Over the years the standard has been upgraded, first to a quartz crystal oscillator, through a series of atomic oscillators, to the present cesium beam accurate to a part in 10^{13}. And there are demands for even higher accuracy, demands that will be met by a continuing research program staffed by high quality, dedicated scientists.

NBS has kept pace by establishing new programs to meet new challenges. For example, development of the laser in 1960 not only opened a host of scientific doors but also created some urgent—and difficult—measurement problems. NBS responded by offering laser wavelength calibration services and, over a limited range, energy calibrations as well. At the beginning of the computer era 25 years ago, NBS played a key role in the development of computer technology and the building of some of the first electronic computers. Today, through its Center for Computer Sciences and Technology, NBS is providing technological leadership in the development of more effective ways to use computer technology to benefit society.

The NBS Center for Building Technology has provided the construction industry with a new perspective on specifications of building materials, as well as tests and methods for insuring performance. The fire research program has established standards and tests for flammable fabrics which protect the public and is developing standards for fire protection equipment.

The rate of change in our society is accelerating—the remaining years of the 20th Century will doubtless see even more rapid change. This will increase the demands on NBS.

Some demands can be anticipated, such as the potential use of extremely low temperatures in our electrical power network. The loss of electrical resistance in metals at low temperature should be exploited in technology for generating and distributing electricity. NBS is already at work in this field, preparing a program that

Procedures were developed at NBS, in cooperation with Libby-Owens-Ford, for the preservation of the original parchment documents of the Declaration of Independence and the Constitution (1951).

will lead the way in joining low temperature and electrical technologies.

While many changes cannot be foreseen, NBS is maintaining an excellent, flexible, multidisciplinary staff that is constantly in touch with the needs of society. This has been the NBS approach over its 70-odd years, an approach that has served society well, and an approach whose intelligent application will meet the needs of tomorrow.

Fluid meter under test at the Cryogenic Flowmetering Facility

INSTITUTE FOR BASIC STANDARDS

THE Institute for Basic Standards' mission is the Custody, Maintenance, and Development of the National Standards of Measurement, and the provision of Means and Methods for Making Measurements Consistent with Those Standards.

This mission places IBS at the heart of the National Measurement System. The primary goal of a National Measurement System is compatibility—every participant (individual or organization) must be compatible in his actions and decisions with others. Consider the need for compatibility in the measurement of one quantity—time. One person might check his watch with a radio station, another by calling the telephone company, and a third by calling Western Union. Yet each of these three people would expect the time involved to be the same. It is the same because the radio station, the telephone company, and Western Union all get the correct time from radio station WWV, operated by the Time and Frequency Division. This same need for compatibility can be traced in the other quantities of measurement.

IBS deals with the highest levels of accuracy, for which it is hard to see the day-to-day utility. The utility is to be found in the needs for compatible measurement in a highly industrialized society, which typically become apparent only to the specialist.

This 30-meter laser interferometer, located in a gold mine near Boulder, Colo, can detect vibration amplitudes as small as 5×10^{-13} meter. Earthquakes, solar and lunar tides, and rock deformation are being studied with this instrument by Judah Levine.

IBS relates most closely to the scientists and engineers who work on the National Measurement System and to the instrument manufacturers. This is a $6 billion industry with a favorable trade balance. Its growth and size illustrate its relative importance to the rest of industry and commerce, since other industries buy instrumentation to increase their own productivity.

All these instruments must be made to give compatible readings at levels of accuracy determined by the manufacturers' specifications. This is accomplished in general through the use of secondary standards, which in turn are calibrated against primary standards which IBS provides and maintains. The National Measurement System is thus a network that ensures compatibility—commercial, industrial, and scientific.

There is an intimate connection between the National Measurement System and science, in particular the so-called Laws of Physics. This connection leads to an International System of Units for physical measurement. At the core of the International System of Measurements there are only seven base units. From these seven are derived all of the other quantities used by science, engineering, technology, and commerce.

It will be impossible to describe all areas that IBS is involved in, in relation to the system of physical measurements, let alone all the ways in which this work relates to users. Therefore, this chapter will:

1. Discuss technical work and applications

related to one of the seven base units, namely the unit of length.

2. Discuss one of the derived units, the unit of energy, and specialize in energy in the form of electromagnetic radiation.

3. Attempt to take a crosscut of all IBS technical programs, showing how they can be grouped into different kinds of services. The intention in doing this is to give specific examples that will illustrate how IBS work provides distributed benefits to government programs, the public in general, industry, and science and technology.

THE UNIT OF LENGTH—THE METER—A BASE UNIT

There are a large number of length measuring devices available, ranging all the way from the Krypton Lamp which defines the unit of length, to lasers stabilized by saturated absorption, down through practical gages that the Bureau calibrates, thereby transferring to users in a directly useful, as well as compatible fashion, the international standard of length. Scientists in the IBS Quantum Electronics Division have played a prominent role in developing the stabilized lasers mentioned above. Such devices may well become the defined length unit of the future.

Length standards—gage blocks, balls, cones, rings, plugs, and angles—are workhorses of the engineering world. Of

◆An interferometric lens-testing system that provides real-time determination of the optical transfer function has been developed by D. N. Grimes.

particular interest are the American Petroleum Institute thread gages, adopted as standards by the whole international petroleum industry, even in Iron Curtain countries. The specifications of these threads originate, in fact, from the API headquarters in Texas, and the threads are known worldwide as the "Texas Threads."

One of the most important improvements taking place at the present time is the use of the laser in length measurements. For length measurement, the laser can be used in two ways:

1. By sending out a short pulse of light, and measuring the time of travel back and forth between two points, as in the retro-reflectors left by Apollo 11, 14, and 15 on the moon. IBS staff members at the NBS Boulder Laboratories have played an important role in this experiment. From this work valuable information is being obtained on lunar motion and earth angular position, to an uncertainty of about 20 meters in a light path of nearly a billion meters. Potential improvements in accuracy can reduce this uncertainty to only a few centimeters. This work may lead to improved knowledge of crustal motions in the earth, even permitting a direct measurement of continental drift, which has both geophysical and astronomical importance.

2. By actually counting one-by-one the wavelengths of light. A commercial laser system is being presently employed at NBS for measuring long gage blocks and coil forms. This is the type of laser instrumentation which is evolving for the control of machine tools as they simultaneously gage and shape materials. The machine which sees and measures as it cuts is the embodiment of high-technology productivity—it does three jobs at once. All of these benefits from laser-control technology are potentially applicable to numerically controlled machine tools, which now represent 20 percent of basic sales of machine tools. Accuracy and precision are absolutely critical to this $1.6 billion tool industry, which is facing tough international competition.

UNIT OF ENERGY: THE JOULE—A DERIVED UNIT

Energy comes in many forms: mechanical, thermal, electromagnetic, and in other ways. For the moment, let's concentrate on the applications of measurements of electromagnetic energy.

For 60-hertz power, IBS provides calibration of reference standard watthour meters. To give some idea of the effect which this has, $22 billion worth of electrical power was sold in the United States in 1970. Reliable and accurate meters sell the output of this huge electrical system and monitor its productivity. IBS also performs calibrations related to the metering of high ac and dc voltages, necessary for tying high power grids together.

In the radio-frequency part of the spectrum, the Institute is active in telecommunications and antenna gain measurements. For example, IBS calibrated

In 1914 Frederick Kolster developed a radio compass that enabled a ship to establish its position by determining the direction of broadcast stations.

Using a technique invented by William E. Hoke, the Bureau produced 50 precision sets of gage blocks for use by American industry during the first World War.

the small gain-standard measuring horn, part of the JPL Goldstone deep space tracking station. The cost of the horn is only a tiny fraction of the whole system expense. Many large communications antennae have had to be overdesigned and overbuilt (from an engineering point of view) because of a lack of capability for measuring their gain characteristics. Accurate information is also available in planning the performance and susceptibility to "jamming" of military radar systems.

In the microwave part of the spectrum the interaction of electromagnetic fields with atoms is used to operate the cesium beam atomic clock. This type of clock embodies the international definition of the base unit, the second, which is now maintained with an error of 1 second in 30,000 years.

In the visible part of the spectrum, techniques have been developed to calibrate instruments that measure the power output of lasers. This is important, as lasers are rapidly coming into general use for eye surgery, cutting cloth for garments, and making tiny holes in diamond dies. Such widespread applications require accurate power measurements to determine and maintain safe radiation levels.

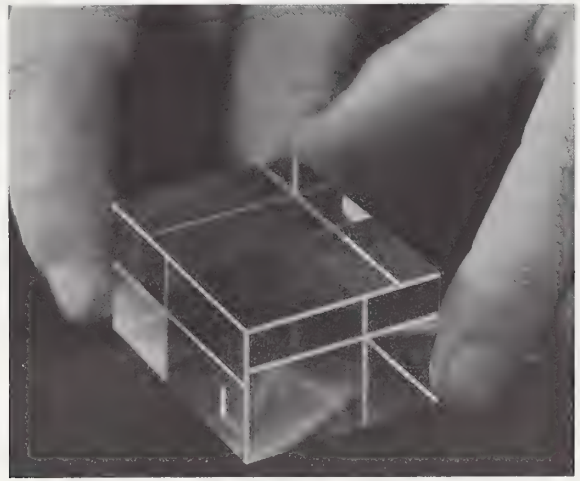
In the x- and gamma-ray region of the spectrum, IBS is involved with dosimetry measurements to protect the health of medical patients, and work has started on new, sharp, high-intensity K x-ray beams which will assist with giving finer control of x-ray machines, so that the patient may be submitted to less total exposure.

This rapid tour across the ranges of the electromagnetic spectrum has shown many places where IBS is doing practical work to make precise energy measurements more useful.

BENEFITS FROM OUR SERVICES

A somewhat different approach can be taken by grouping the total outputs and services under various headings.

First of all, with regard to Calibration and the Testing, general policy is to provide services only when they are not adequately available elsewhere from commercial sources. Nevertheless, we calibrate about 1,300 items monthly and our list of industrial and commercial customers reads like a



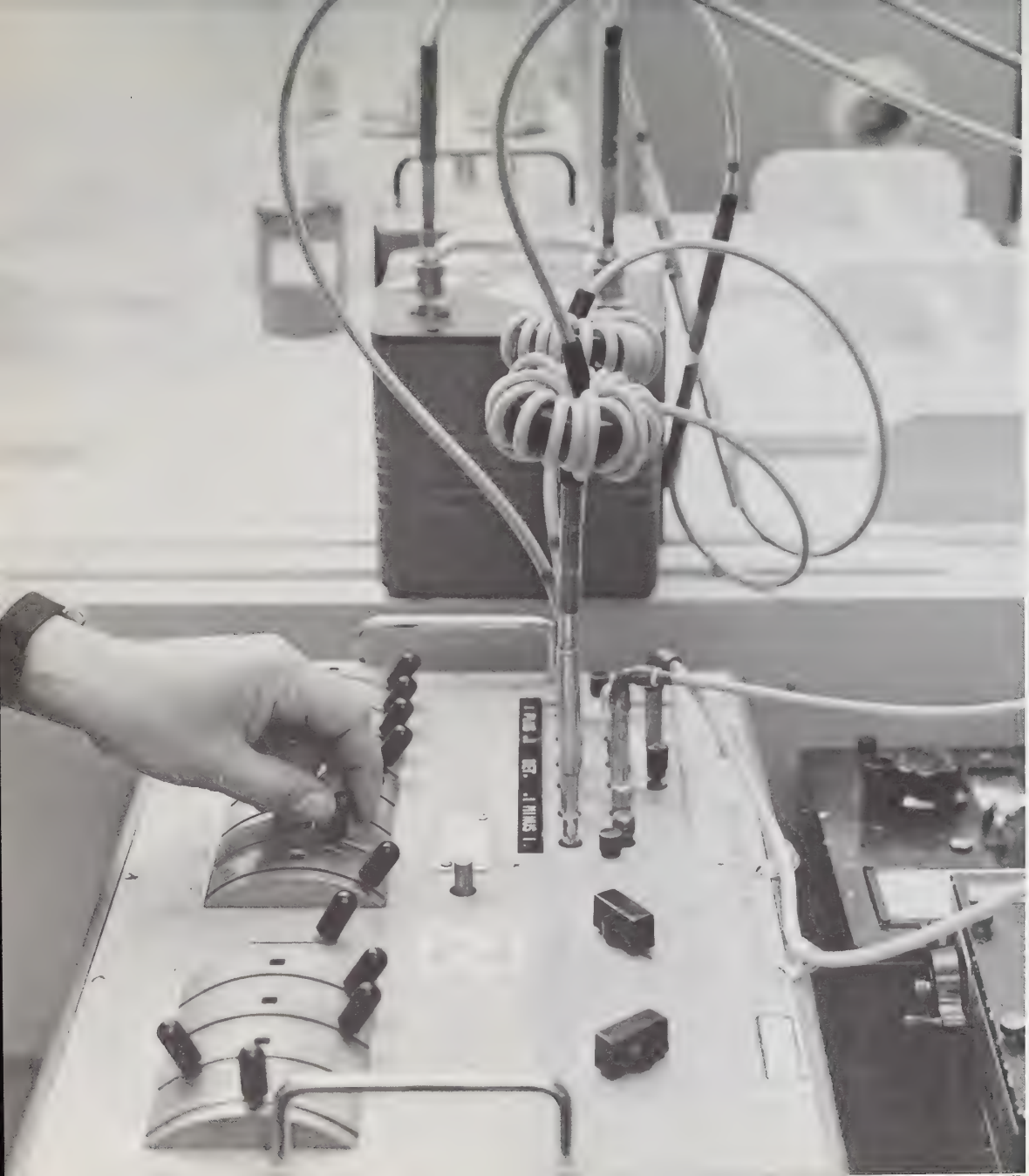
Thomas Proctor determined the velocity of sound in this borosilicate block by measuring the time required for a sound pulse to cross the block and be reflected back to a transducer applied to one of the faces.

directory of U.S. corporations. The value of the calibrations must be significant in commercial terms and, in fact, in some individual cases we have specific proof of a high leverage.

The Measurement Assurance Program (MAP) is designed to see that the user's needs are actually being met in his own laboratory or on his test bench. The possession of an NBS calibrated standard does not by itself ensure good measurement and, in fact, in some cases one has to worry whether the standard even survived the trip back home. MAP is a program to test the user's measurement processes as he performs them in his own laboratory. Its prime tool for doing so is a "round robin" in which a test object is measured by NBS and the members of a group of cooperating laboratories. Comparison of the results discloses those members who are obtaining inaccurate results. Then analysis by NBS of how their measurements are affected by procedural variations and by environmental conditions in their laboratories serves to pinpoint the sources of the error. Periodic repetition of this process then monitors the members (including NBS) and ascertains if that segment of the measurement system remains under control.

Testing, which involves the properties of materials or structures, is carried out in

Shown here is a highly stable tungsten-strip lamp that serves as a basis for realizing the International Practical Temperature Scale above the gold point and as a standard for spectral radiance measurements.



adjustment with the needs of the user.

Consulting and Advisory Services are undertaken as a result of the particular know-how of our staff. IBS has, for example, made substantial technical and consultative inputs to three major Government reports on the problem of noise pollution—those of the Departments of Housing and Urban Development, Commerce, and the Environmental Protection Agency.

The role of "independent 3d party" is another service for which we are frequently called upon. Only general confidence in NBS as a "disinterested" source of testimony makes this contribution possible. NBS is one of the great laboratories of the world; we are justifiably proud of it, and feel that our real purpose is to be helpful. These examples may be instructive in illustrating how and where we help.

There is an intimate link between being able to make measurements, and data on the properties of material. An example is recent work on the thermal properties of oxygen, hydrogen, helium, and liquefied natural gas. Liquefied natural gas is difficult to store, to transport, and to meter. IBS advisory services and the research behind them, partially sponsored by the American Gas Association, have contributed broadly to the healthy growth of the young cryogenics industry.

The Cryogenics Division is taking steps under Presidential initiation to stimulate the

♦A special capacitance bridge was designed and built at NBS for use in calibration services.

application of superconductivity in large electrical machinery. The groundwork of research has been done, and engineering benefits—efficiency and increased capacity— are clearly in sight.

Next, in the field of Mine Safety, IBS is working with the Bureau of Mines to apply Very Low Frequency electromagnetic waves as a new way of locating and communicating with trapped miners.

In the field of Aircraft Safety, instruments and test methods for evaluating runway lighting have been developed, in conjunction with the FAA and the Navy. Standards have been developed to assure that all cockpit lights are above, but close to, the threshold for low-level vision. These low levels of illumination require a different scale and standard from normal-level lighting.

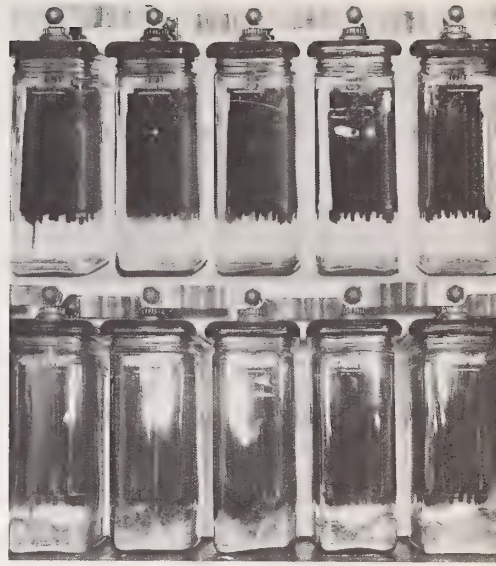
Time and Frequency and their dissemination to users are responsibilities specifically designated to NBS. In fact, the workhorses of the timing community are WWV in Fort Collins, Colo., and the recently rebuilt station WWVH in Kauai, Hawaii. NBS has made a comprehensive study of future methods for improving timing signals which will be generally available. One potential is the technique of carrying a time signal on commercial television broadcasts. Tests of this technique, in which time is displayed on the screen of specially adapted receivers or used to control a clock at the receiver, show great promise for a national system accurate to 1 μs or better.

H. S. Bowman makes a bone conduction measurement on E. L. Smith

The digital coding of information onto unused lines of the TV raster, which was developed for time dissemination, was shown to be adaptable to captioning of TV programs for the hearing impaired and other uses. The system does not in any way interfere with normal viewing of programs.

IBS develops Measurement Methods in many fields, including nuclear energy. For the Integrated Safeguards Experiment, which assures that fissionable materials are not directed to unauthorized purposes, extremely accurate weighing and volumetric measurements have been developed for shippers and receivers of large amounts of fissionable material. For the Navy, in connection with the McMurdo Station reactor in Antarctica and in other connections, IBS developed and operates low-level radioactivity monitoring techniques for effluents.

With regard to neutron standards, particularly as they affect the fast breeder program, there is an expanding program



In 1949, Bureau test on battery additive AD-X2 showed it—like all other additives tested over the previous 30 years—had no positive effect on battery life or performance. In fact, a negative effect was found during a 10-year field trial. Three of the batteries used as part of the NBS dc power supply (top) were treated with AD-X2 and returned to service; three companion cells were not treated. After 10 years of routine service the treated cells (second, third, and sixth, left to right, bottom) showed more deposit and their averaged electrical capacity was but 3.5% of the untreated cells.

Raymond Driscoll and Peter Bender redetermined the gyromagnetic ratio of the proton with increased accuracy. The known magnetic field of the solenoid (center) causes the protons in water to precess. The larger outer coils counterbalance the earth's magnetic field (1958).

centered around the measurement of neutron fluxes and precision neutron cross sections.

Over the years NBS experts have contributed to the work of several Nobel prize winners. In the summer of 1931 Harold Urey, lecturing at Johns Hopkins, discussed his newly detected satellite hydrogen line, that might be heavy hydrogen, with Fred Mohler of NBS. Fred suggested that Ferdinand Brickwedde of the NBS Low-Temperature Laboratory, who was studying ortho-para conversion of hydrogen, might be able to help. Successive distillation of liquid hydrogen at NBS led to concentrations of heavy hydrogen sufficient for unambiguous proof—a finding announced by Urey, Brickwedde, and Murphy in the March 1932 NBS Technical News Bulletin. This event signalled the start of NBS involvement in atomic energy, and in contributing to the work of Nobel Laureates. Interestingly, the energy extremes—nuclear energy and near absolute-zero temperature—seemed a common feature.

In 1956, C. S. Wu brought the Bureau's capabilities in nuclear paramagnetic cooling together with Yang and Lee's suspicion that all was not right with parity conservation in weak interactions. This experiment, which involved Messrs. Ambler, Hayward, Hoppes, and Hudson of IBS, together with Miss Wu, helped to trigger a Nobel prize for Yang and Lee.

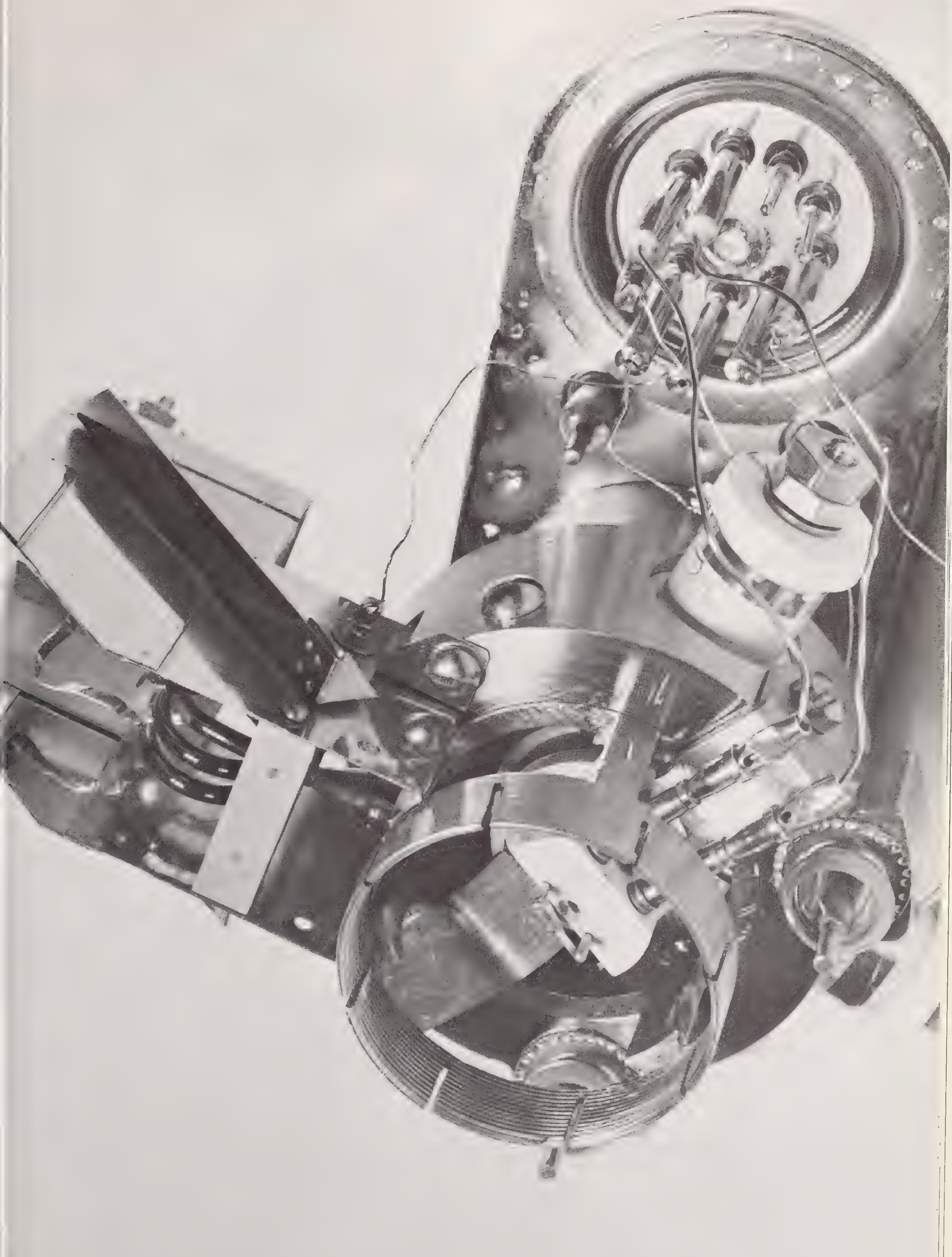
More recently Luis Alvarez was gracious enough to say in his Nobel Laureate acceptance speech, when discussing problems involved in building and housing the 72-inch hydrogen bubble chamber, "We were also extremely fortunate in being able to interest the Bureau of Standards in the project. Dudley Chelton, Bascom Birmingham, and Doug Mann spent a great deal of time with us, first educating us in large-scale liquid hydrogen techniques, and later cooperating with us in the design and initial operation of the big chamber."

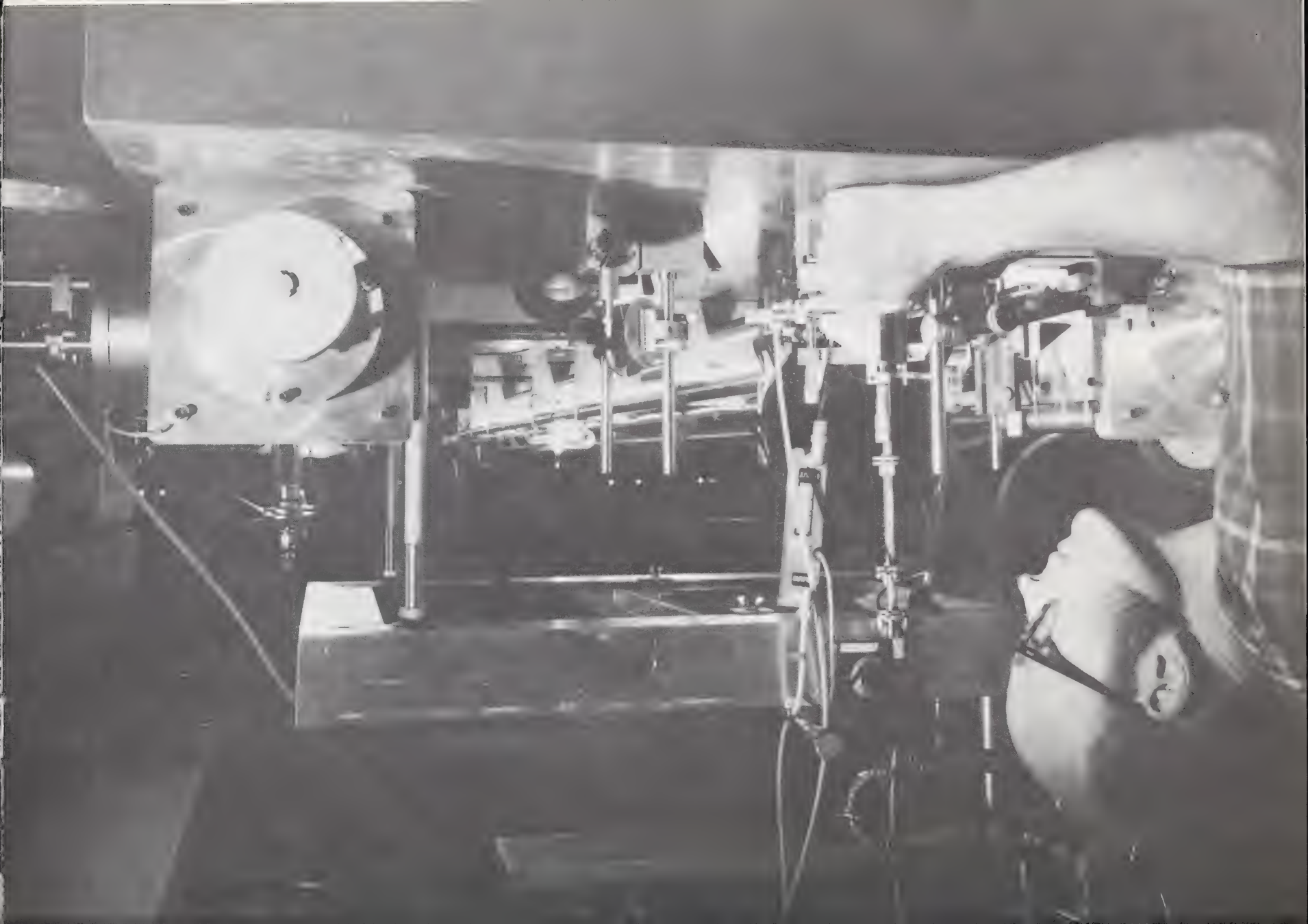
LOOKING FORWARD IN BASIC STANDARDS

Modern metrology is becoming increasingly based upon the properties of atomic and molecular systems, it being accepted that such properties are the same everywhere and invariant in time. The behavior of such systems obeys the laws of quantum mechanics rather than classical mechanics, hence, the name "quantum metrology." The name also encompasses macroscopic quantum effects, such as appear in superconductivity and the Josephson effect.

A concomitant result of the dependence of our basic standards of measurement upon quantum metrology is an intertwining of Base Units of Measurement and the Fundamental Physical Constants, such as the speed of light, which relates the unit of length to the unit of time. Indeed then, physical constants, or combinations of them,

A noncontacting device that measures the microtopography of metal surfaces is now under development. It also produces secondary electron emission pictures of the surface.





play an important central role as transfer constants relating measurable physical quantities of different kinds. Thus, accurate values of them are not only important to the program of science itself, but also to the progress of metrological science. Some consequences of the trend to quantum metrology follow:

New Definition of a Length Standard

IBS continues its program to encourage adoption of the 3.39 μm He—Ne laser, stabilized by saturated molecular absorption in methane, as the new definition of the meter; while at the same time developing other lasers as secondary standards, particularly in the visible region.

Technological Implications

The stability of molecularly stabilized oscillators has proven to be such that their precision greatly exceeds that of the presently defined length standards and begins to rival that of time standards. Thus, IBS programs should be reviewed in the broader sense of opening up the range of the electromagnetic spectrum by the development of highly stable and coherent oscillators. Of central importance in these technological developments is the frequency locking of a chain of oscillators from the microwave frequency standard up to lasers in the visible region.

♦*In February 1972 Dr. K. Evenson reported the highest frequency measurement made to that time—the frequency of the infrared He-Ne laser line at 88,376,245 million hertz. Since the wavelength had already been determined in terms of 86 Kr, knowledge of the frequency permitted calculation of the speed of light with*

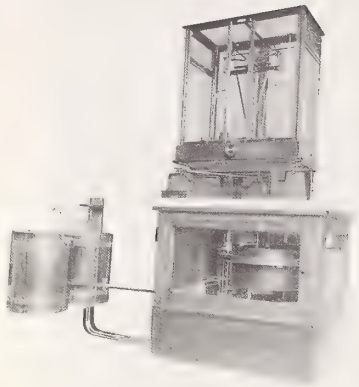
Implications for New Physical Experiments

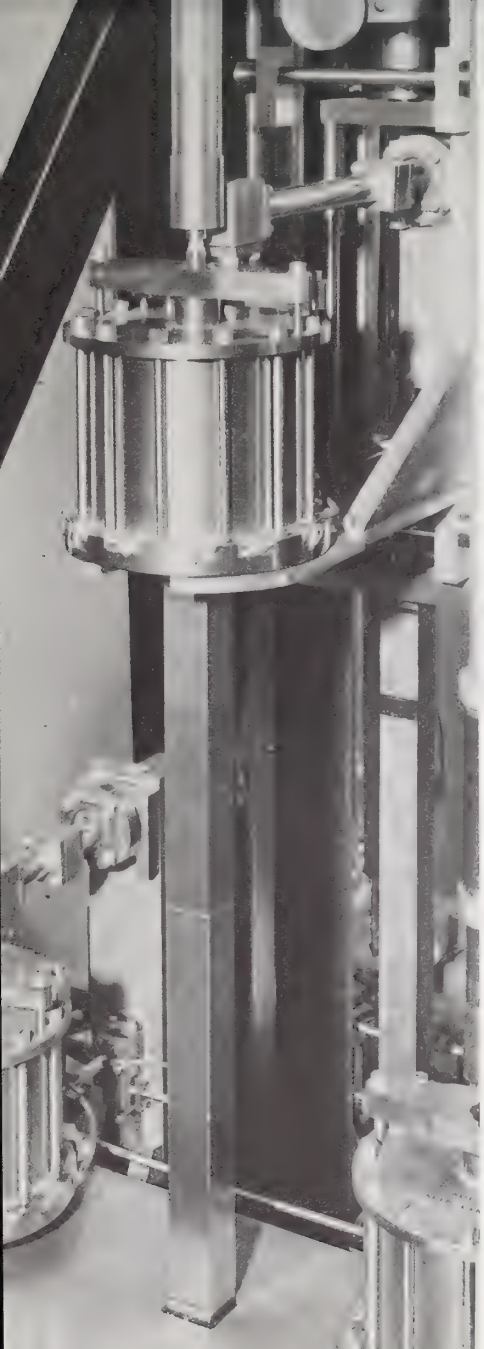
The ability to have optical frequencies stable to parts in 10^{14} or better opens up the possibility of verifying to a higher accuracy certain properties concerned with the isotropy of space.

Implications for the Definition of the Kilogram and Mole of the Accurate Measurement of Atomic Distances

The continuation of the program on measuring interatomic distances accurately by the simultaneous counting of x-ray and optical fringes will enable a more accurate value for the x unit to be obtained. Experiments aimed at characterizing highly pure silicon with regard to physical purity, chemical purity, and isotope ratio will be completed, which will enable a more accurate value of Avogadro's constant to be determined. The close connection between the kilogram, the atomic mass unit, the mole, and Avogadro's constant allows the possibility—albeit a distant one at present—of defining the kilogram in terms of the mass of silicon atoms. The possibility is a distant one since one is really aiming for a characterization of silicon comparable to the reproducibility of the prototype kilogram, i.e., to a few parts in 10^9.

This current balance was used by Drs. Rosa and Dorsey in 1908 for a precision determination of the ampere.





The Application of the Josephson Effect and SQUIDS to Electrical Standards and the Measurement of Fundamental Constants

The legal volt is now being maintained by NBS through determination of 2 e/h using the ac Josephson effect in superconductors. In these measurements, the voltage of two Josephson junctions operated in series is compared with the emf of a standard cell by means of a special potentiometer. Under this procedure, the mean emf assigned to the reference group of cells will be adjusted periodically to eliminate any apparent variation in 2 e/h caused by drift of the cells' emf. This approach will provide a significant improvement in the long-term maintenance of the U.S. legal volt.

Technological uses of SQUIDS (Superconducting Quantum Interference Devices, based upon the Josephson effect and the quantization of magnetic flux) will find uses in precision magnetometry for applications such as cardiography, geophysics, etc.

SQUIDS will also prove to be useful in the accurate measurement of voltage, current, and power ratios from dc up to microwave ranges.

More precise values of the ratio of fundamental constants h/e and h/m will be obtained using these techniques.

The Josephson junction is being incorporated in a "noise thermometer" for the determination of very low temperatures ($\cong$ .01 K) on the absolute scale.

Part of the accurate manometer used in the continuing gas thermometry project. A column of gage blocks is used to establish the height of the center cell.

PRACTICAL STANDARDS OF LENGTH AND SHAPE

A generalized three-dimensional measuring machine will be built. Novel designs of surface probes and the measurement of the position of the probe carriage within a volume $\cong$ 1 meter cube, to an accuracy of 1 μm, or better, will be developed. The system will be fully servoed and automated.

Surface topography will be developed and capabilities to measure vertical irregularities of 3 nm will be exploited.

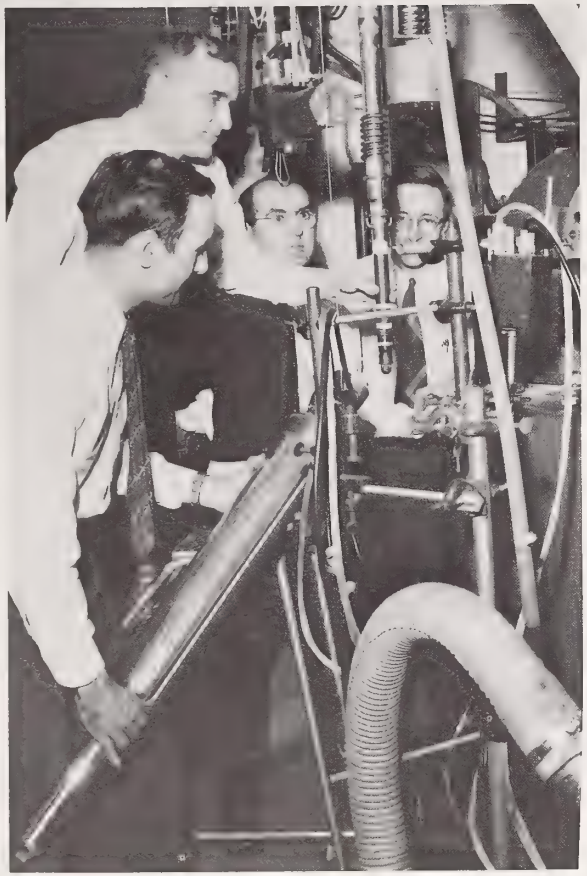
TRANSFER OF MEASUREMENT CAPABILITY

The NBS Measurement Assurance Program evaluates and improves the capabilities of industrial, commercial, and other-agency standards laboratories by analyzing their measurements of standards or instruments furnished by or exchanged with the NBS. It has been tested by measurements of mass and voltage and now is ready to be expanded to other physical quantities for which NBS maintains standards. Also, the procedures will be extended so as to operate between different echelons of standards laboratories within, say, a large corporation or a military service.

TIME DISSEMINATION

The next decade will see time and frequency being disseminated with orders of

magnitude, greater accuracy, and wide coverage using the TV networks and stationary satellites.



The first experiment demonstrating nonconservation of parity in weak interactions was conducted in 1956 by (left to right) Ralph Hudson; Ernest Ambler, now Director of the Institute for Basic Standards; Dale Hoppes; and Raymond Hayward. They determined that the beta emission distributions for cobalt-60 polarized in opposite directions was not the same, proving parity was not conserved.

RADIATION SAFETY

Radioactive standards will be developed and applied to:

1. Quality assurance in radiopharmaceuticals
2. Accuracy of monitoring at very low levels of activity (environmental protection).

More precise methods of measuring x-ray dose will be developed, along with transfer instruments for assuring greater accuracy in medical and biological dosimetry.

An improved instrumental method has been developed for measuring stray microwave radiation (cooking ovens, radars, diathermy, and industrial heating equipment) and will promote its wider use in monitoring compliance with safety regulations.

Instrumental methods will be developed for measuring ultrasonic power. These are urgently needed in medical diagnostics and also in industrial usage of ultrasonics, e.g., testing materials and structures.

NONDESTRUCTIVE TESTING

There are widespread needs for physical methods of testing materials and structures for flaws, with a view especially toward continuous monitoring during active service and the forewarning of imminent failures. The Institute is especially fitted to proceed with acoustic, holographic, x-ray, magnetic, and electric methods of examination.

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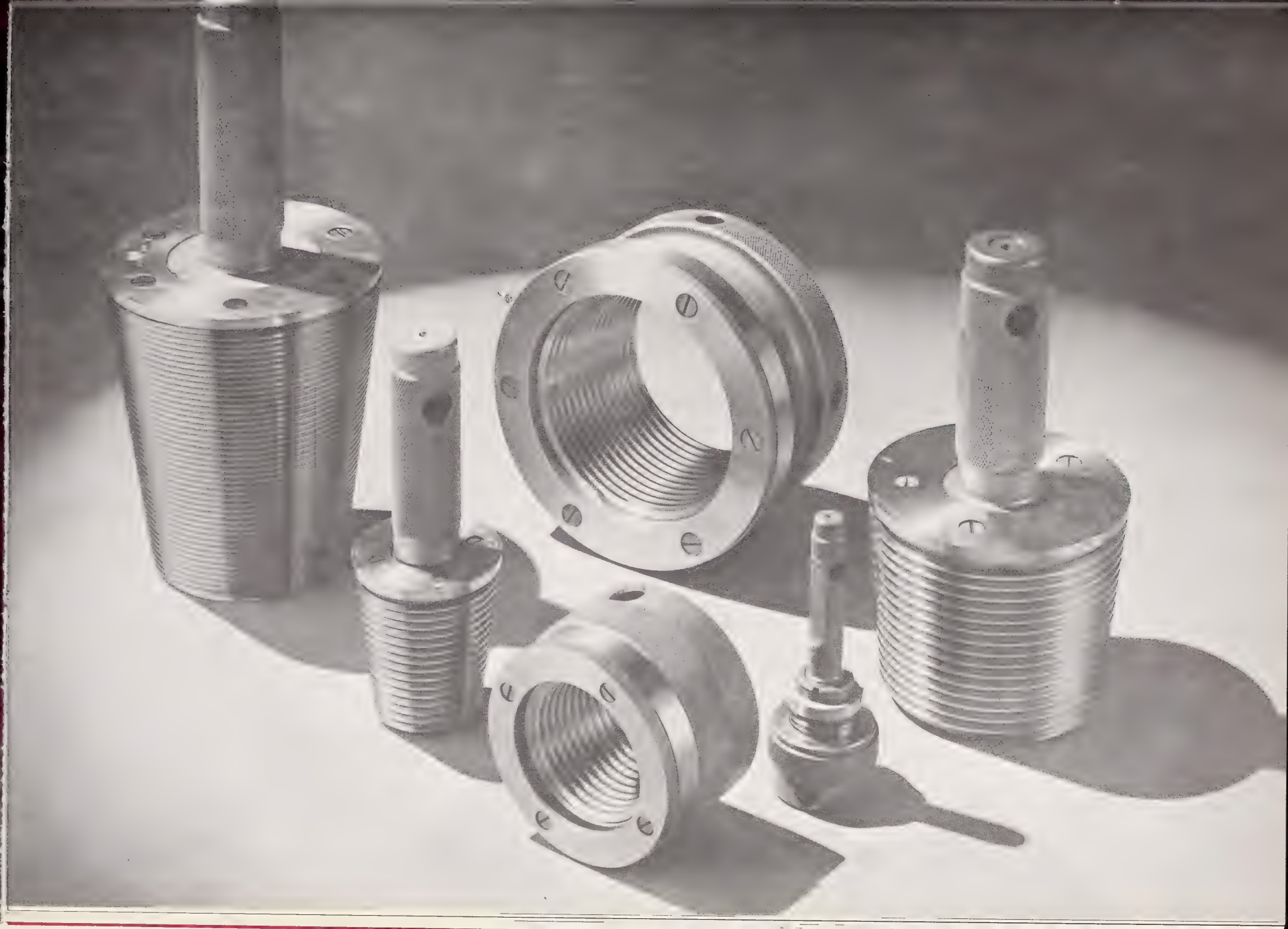
In 1922 Percival Lowell invented a rectifier that made it possible to operate radios on alternating current. This revolutionary development tremendously expanded the market for home radios.

Early apparatus for photographing metallurgical specimens.

SURFACE PHYSICS

Phenomena at surfaces are of great practical importance in solid-state microelectronics, heterogeneous catalysis, adhesion, and composite materials. They also are very challenging and elusive in the laboratory due to the necessity of dealing with single layers of atoms or even individual atoms. Research aimed at mapping surface states on metals, the effects of adsorbed atoms on field- and photo-emission of electrons, methods of producing atomically clean and flat surfaces, and the mapping of surface topography will be expanded. The results will support the use of Auger electron analytical spectrometers, x-ray photoelectron analytical spectrometers, applications of electron scattering in biological materials, and will yield a new and very sensitive electron-emission surface profilometer.

NBS calibrates the American Petroleum Institute gages that are used worldwide in the petroleum industry.



INSTITUTE FOR MATERIALS RESEARCH

THE mission of the Institute for Materials Research (IMR) is to:

- Furnish certified standard reference materials for the calibration of measuring instruments, test methods, quality control, and research;
- Develop new and improved methods for measuring the properties of materials;
- Generate and evaluate scientific and engineering data on well-characterized materials;
- Relate the physical and chemical properties of materials to their behavior and their interaction with their environments;
- Provide advisory, consulting, research, and technical services to other Government agencies in support of their statutory responsibilities.

The mission of the Institute is carried out in six technical Divisions: Analytical Chemistry, Physical Chemistry, Reactor Radiation, Polymers, Metallurgy, and Inorganic Materials; and in two program offices: the Office of Measures for Air Quality and the Office of Standard Reference Materials.

The Institute has a full-time permanent staff of about 460 which includes 330 professionals of whom 180 have Ph.D.'s in science and engineering. In addition, there is a part-time staff of about 125 scientific consultants, research associates, and guest workers. The Institute budget was over $18 million in Fiscal Year 1972. This included expenditures of approximately $12 million in congressional appropriations, $5 million in other agency support, and about $1.2 million for our Standard Reference Materials Program which is reimbursed by sale of Standard Reference Materials.

◀Looking into the ultra-high vacuum environment of an instrument used in studies of metal oxidation. A metal specimen disk is heated by electrons from the wire coil, and then exposed to controlled amounts of oxygen while being examined by ellipsometry and low-energy electron diffraction.

IMR PROGRAMS

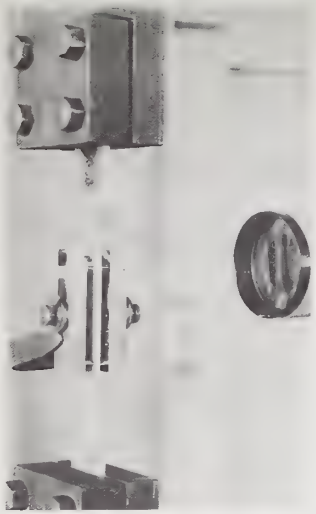
Current IMR technical activities are in the following program areas:

- Materials Measurement Methods and Standards
- Materials Science and Technology
- Standard Reference Materials
- Measures for Air Quality
- Technical Services and Cooperative Research

These programs are described briefly below.

Materials Measurement Methods and Standards

This program is concerned with the preparation and purification of materials; their thorough characterization as to chemical composition, impurity content, and physical structure; the development of new methods for measuring the properties of materials, and the generation and evaluation of needed data on the properties of materials. The materials measurement methods and standards activities provide the essential base upon which all other IMR programs depend.



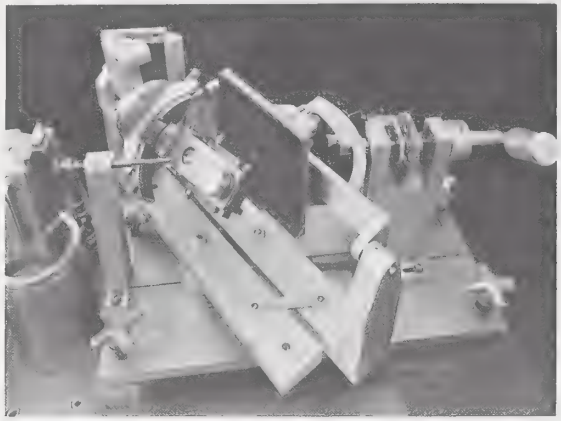
In 1923 Lewis B. Tuckerman devised an optical strain gage by which deformations as small as 2 millionths of an inch could be detected. This device is still in wide use.

An excellent illustration of the development of new measurement techniques comes from research on the high pressure properties of materials in our Inorganic Materials Division. This work exploits the diamond-anvil pressure cell, invented and developed at NBS.

In the small cell between two diamond surfaces, pressures up to 100 kilobars (1,450,000 pounds per square inch) may be generated. The diamond window of the cell is transparent to x-ray, visible, infrared, and ultraviolet rays, permitting direct observation of the changes that occur in materials as pressure is applied to them. A persistent deficiency in using the diamond cell was the inability of scientists to measure the pressure continuously, rapidly, and accurately. To overcome this deficiency, our scientists have developed a new pressure-measuring technique which utilizes a pressure shift in the sharp R-line fluorescence spectrum of ruby. This makes possible the acquisition of needed data and information on materials intended for use in a high-pressure environment.

This cell was used at the request of the Picatinny Arsenal to measure the high-pressure properties of the most commonly used explosive detonator, lead azide. IMR scientists found that lead azide was stable to pressures in excess of 20 kilobars (290,000 pounds per square inch) which is much higher than is found in the chamber of a gun, even during firing. It was concluded that the detonation of lead azide was not a result of the absolute pressure, but was probably caused by the rate of change of pressure and possibly by the rapid generation of heat that occurs as the detonator is struck.

An example of accomplishment in the area of data acquisition is the precise determination of the numerical values in the Mark-Houwink equation which defines the relationship between the molecular weight (size) of a polymer (plastic) and the viscosity of a solution of the polymer in an organic solvent. This relationship is extremely important to the plastics industry for it provides a quick, simple, and accurate method for determining the molecular weight of the polymer chain since the viscosity of the polymer solution is easy to measure. It is the molecular weight of the plastic which greatly influences its properties, for example, its mechanical strength. Scientists in the Polymers Division

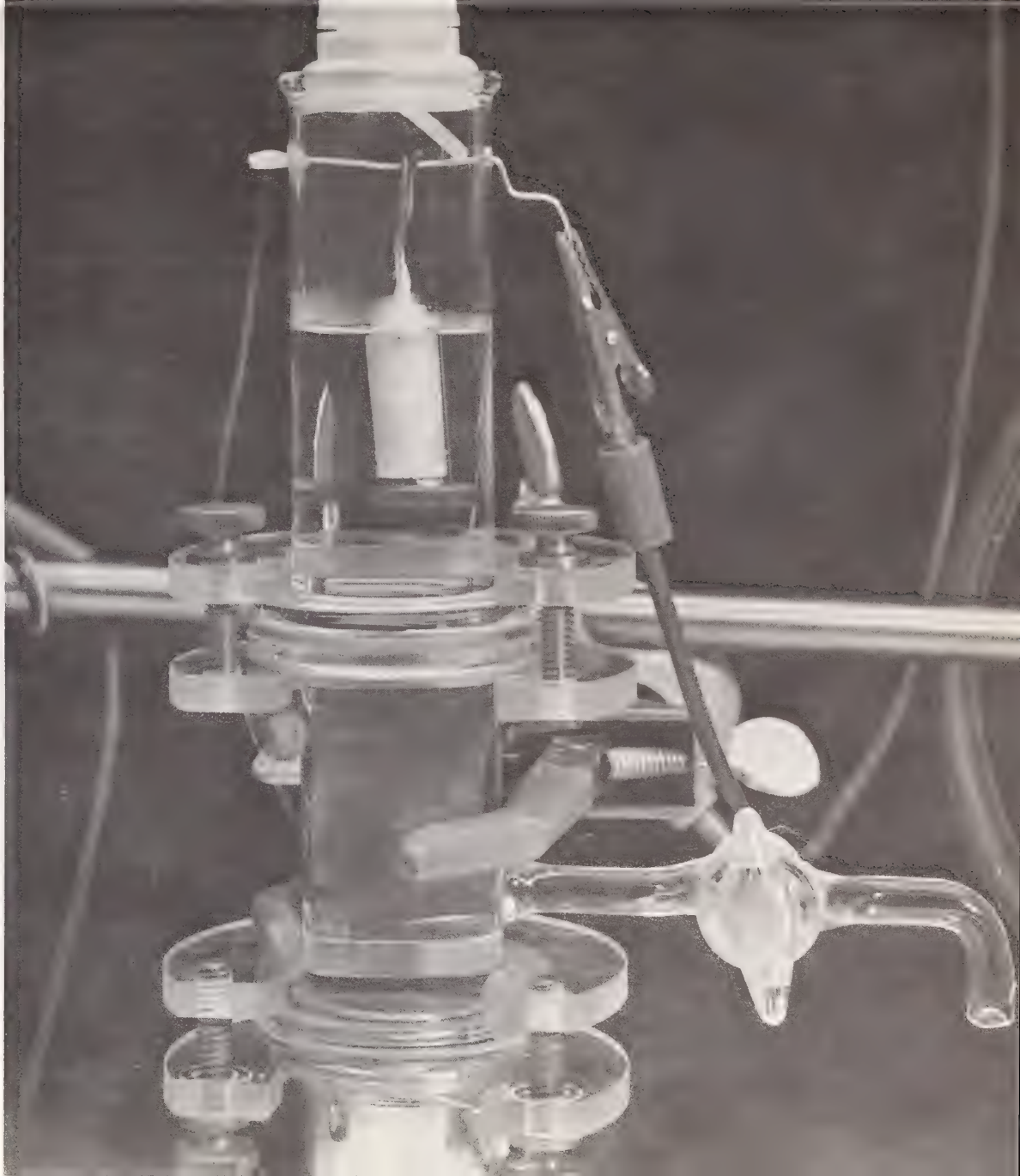


The high-pressure diamond cell developed at NBS has been used for several years to study crystal and molecular structure of materials at pressures up to 60 kilobars. Here the cell is mounted on a goniometer in the precession camera so that it lies between the x-ray source and a photographic film.

have carefully measured the numerical constants in the equation defining the viscosity relationship in the case of polyethylene, a plastic produced in billion-pound quantities last year. In contrast to the viscosity characterization which can be calibrated by the universal equation, other easily and widely used techniques for measuring molecular weight in industry must be calibrated individually with standard materials. One such technique is Gel Permeation Chromatography. For the calibration of this instrument, scientists in the Polymers Division have produced a Polyethylene Standard Reference Material for which they measured and certified the molecular weight characteristics. Thus this material can be used for calibration purposes. Further research is being carried out either to improve existing or to develop new absolute molecular weight measuring techniques for application to calibration problems like those described above. The work is also currently being extended to other important plastics.

Materials Science and Technology

The objectives of this program are the development of concepts which explain the properties and behavior of materials and the application of knowledge gained to the



The atomic weight of zinc was recently measured with high accuracy in this coulometric cell.

solution of materials problems in a number of important areas. The emphasis in this program is on solving materials problems rather than developing measurement methods and standards per se, although on many occasions measurement methods must be developed or refined in order to solve the problem at hand.

An example of such an activity is the work on the corrosion of metals which has been actively pursued for many years in the Metallurgy Division. Data and information which have been obtained on corrosion rates under various conditions are of extreme importance to the metals and construction industries. It is estimated that

Since early 1963, Drs. Dolphus E. Milligan and Marilyn E. Jacox have obtained infrared spectra of many free radicals through isolation in cold inert gas matrices. Such spectra are important in air and water pollution and analysis.

corrosion costs the U.S. consumer more than $10 billion per year. A study of the corrosion of steel pilings in soils by this group led to the finding that piles should be driven into the soil—thus depriving them of oxygen that causes rusting—instead of digging the soil, which admits oxygen, before placing the piles. The results of this study, which were reported in NBS Monograph 58, were received most enthusiastically by engineers in this country and abroad, as evidenced by the 35,000 requests received for the publication. These activities show the kinds of research done in acquiring data on the properties and behavior of materials. At the forefront of science and in areas of technological importance, such activities are of considerable value to science, industry, and the public welfare, including defense.

Another example of IMR work in this program is the Inorganic Materials Division studies of the factors controlling strength and deformation of strong, hard materials (especially glass), the processes leading to loss of strength, and techniques for the measurement of such strength. This research has led to the development of unique test methods for the strength of glass windows and plates as a function of surface condition. These are now being developed as ASTM standards and are being used to provide data to designers of windows for deep diving submarines, aircraft, satellites, and to users of electronic substrates. A second test method developed has determined the fracture surface energy, a fundamental parameter controlling strength, and the influence of chemical environment on the strength. This method is being used to provide data to the Army and to NASA.

As part of both the Materials Measurement Methods and Standards and the Materials Science and Technology Programs, IMR does some exploratory research aimed at providing a better understanding of the behavior of materials. A good understanding of the behavior of a material is in general a boon to its eventual proper use. IMR also has a number of data compilation efforts that are closely associated with these programs. The Institute is one of the principal contributors to the National Standard Reference Data Program and provides carefully evaluated and meaningful data on the properties of materials and chemical compounds to the Nation's scientists and engineers.

Standard Reference Materials (SRM's)

Since 1910, NBS has provided a wide variety of materials that are used by science, industry, and technology to accurately calibrate many kinds of measurement systems. Over 800 Standard Reference Materials (SRM's) are available from NBS, and about 30,000 of these are sold each year.

SRM's are used in many areas:

• **Environment:** NBS issues about 20 SRM's for calibrating instruments used to monitor the levels of both natural and man-made pollutants in the atmosphere. For example, SO_2 permeation tubes are available to

The competence of Martin Shepherd and the Gas Chemistry Section in the field of atmospheric analysis resulted in their participation in early attempts to define the composition of air samples from the stratosphere. In 1935 samples were collected by the balloon Explorer II, flown to a height of 73,000 feet as a joint project of the National Geographic Society and the Army Air Corps (photo courtesy National Geographic Society).

calibrate equipment used in both the laboratory and field to measure this pollutant.

• **Health:** Over 15 SRM's are issued, including cholesterol, which are used to control accuracy of measurements in clinical laboratories.

• **Biology:** Bovine liver and orchard leaves are certified for trace elements such as mercury, lead, cadium, copper, iron, and nickel.

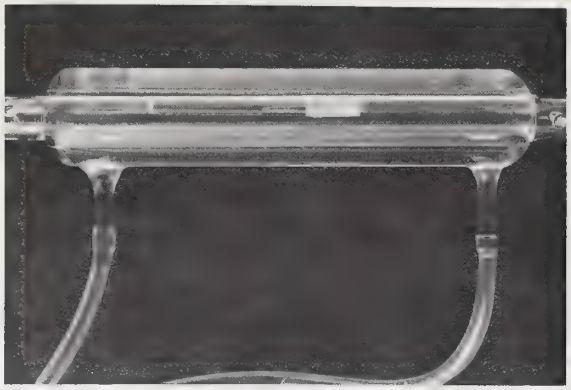
• **Quality Control and Productivity Enhancement:** Iron and steel standards are used to calibrate rapid and accurate methods for analysis of these metals during their manufacture.

• **Energy Production:** Isotopic abundance and assay SRM's for plutonium and uranium are issued for use in production of nuclear power.

• **Scientific Research:** SRM's are available to calibrate instruments used to measure a variety of physical properties such as freezing point, vapor pressure, radioactivity, and others.

• **Transportation and Defense:** Metallo-organic compounds, such as an oil-soluble copper SRM, are used to control analysis of engine and bearing oil for the purpose of preventive maintenance.

As an example of how an SRM is employed, the copper metallo-organic SRM is used to determine the performance characteristics of engines in the trucking and railroad industries, and in aircraft of the Department of Defense. Periodic chemical analysis of the copper content of the lubricating oils of these engines can predict imminent failure of a copper-containing bearing because a sudden increase in the amount of copper in the oil would signal such an event. These oils are analyzed with a spectrometer whose accuracy and constancy of operation is assured through calibration with the NBS oil-soluble copper SRM. An early success of this technique was the detection of an incipient failure in an engine of an aircraft used by the then President of the United States.



Nitrogen dioxide permeation device being evaluated in the laboratory. The small tube within the condenser contains liquid NO_2 which permeates through a porous plug at the right-hand end, the permeation rate being a function of temperature.

NBS began producing optical glass when European supplies were cut off by WW I. This expertise led to the casting of a 69.5-inch telescope mirror for Ohio Wesleyan University, the largest made in this country before 1928. Prof. Crump of Wesleyan University and Dr. Burgess, NBS Director, inspect the disk after a mounting hole had been drilled.

Measures for Air Quality Program

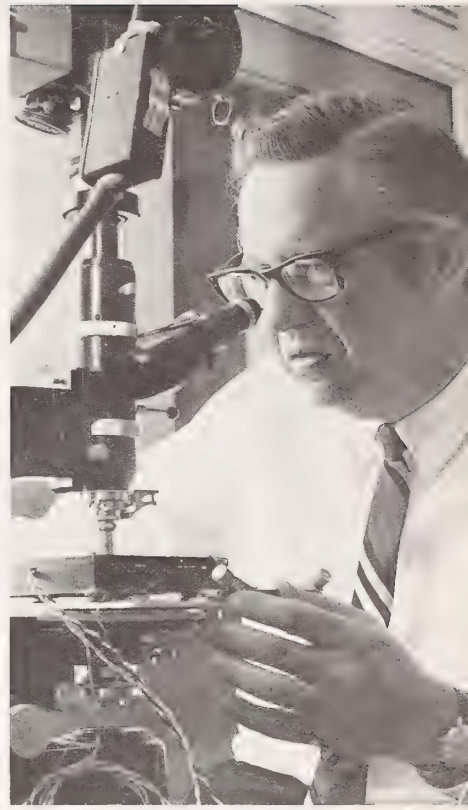
The concentration of pollutants in urban air must be measured to determine the extent of the community's exposure in order to predict and control damage to health and to permit the accurate determination of

pollutant levels for monitoring and control programs. While there is a dramatic increase in deaths after a pollution "incident" (1600 due to the 1952 London "killer smog"), current measurement capability is not good enough to determine a direct cause and effect relationship between specific pollutants and mortality. Neither are the chronic effects of low levels of pollution, i.e., those levels below "incident" conditions, amenable to accurate evaluation. An estimated 1,100 to 2,200 people die each year in New York due to "normal" (nonepisodic) air pollution. Measurement methods now in use often have errors as large as the concentrations being measured, making it difficult or impossible to correlate pollution levels and health effects.

Air pollution abatement measurements also have economic implications since air pollution damages plant life, buildings, and materials. For example, steel corrodes two to four times faster in urban industrial areas than it does in rural communities. The economic importance of the pollution measurement problem is also reflected in control costs. While there is disagreement over exact figures, it is clear that the Nation will spend billions of dollars on pollution control in the next decade and that measurement costs will be a small fraction of that amount. It is important to realize that good measurement capability avoids the need to install and use excessive control capacity.

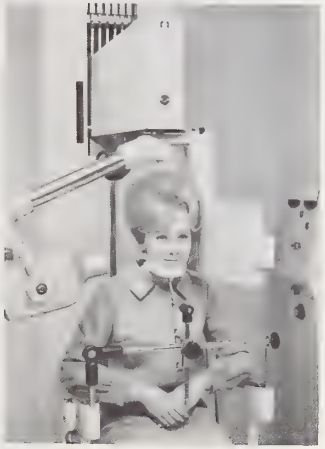
The Measures for Air Quality (MAQ) Program, which was initiated in 1970, attacks the most urgent air pollution measurement and data problems with special emphasis on their quantitative basis and technical credibility to insure adequate but fair abatement and minimize unnecessary restriction on industry and citizenry. Specific goals of MAQ are: (1) the development of a broad approach to the particulate measurement problem via the development of new methodology for particulate size and distribution measurements and for physical and chemical analysis of particulates; (2) the development of precise methods for the analysis of gaseous pollutants through the use of laser and optical methods and the adaptation of existing analytical techniques not now used for air pollution measurements; (3) the development of standard reference materials for the calibration of analytical instrumentation; and (4) the compilation, evaluation, and dissemination of critical data pertaining to air pollution.

Examples of recent accomplishments in this area include the development of a sulfur dioxide permeation tube that serves as a standard reference material to calibrate air pollution measuring instruments and the refinement of a method that utilizes a light-scattering technique to measure the size and size distribution of particulates.



Dr. John D. Hoffman, Director of the Institute for Materials Research, continues his active interest in studies of chain folded polymers.

In cooperation with the U.S. Air Force, NBS developed in 1954 a panoramic x-ray machine that produces a single picture of the entire dental arch in 22 seconds, and cuts absorbed dose by a factor of 10 over multiple-film techniques. The machine is widely used by the armed services, the Veterns Administration, and wherever mass screenings are conducted. Here an x-ray is about to be taken of Rebecca Morehouse.



Technical Services and Cooperative Research

The research and standards capabilities and facilities of all IMR Technical Divisions and programs have been utilized by other Government agencies, industry, national standardization bodies, and the general scientific community to help solve materials problems.

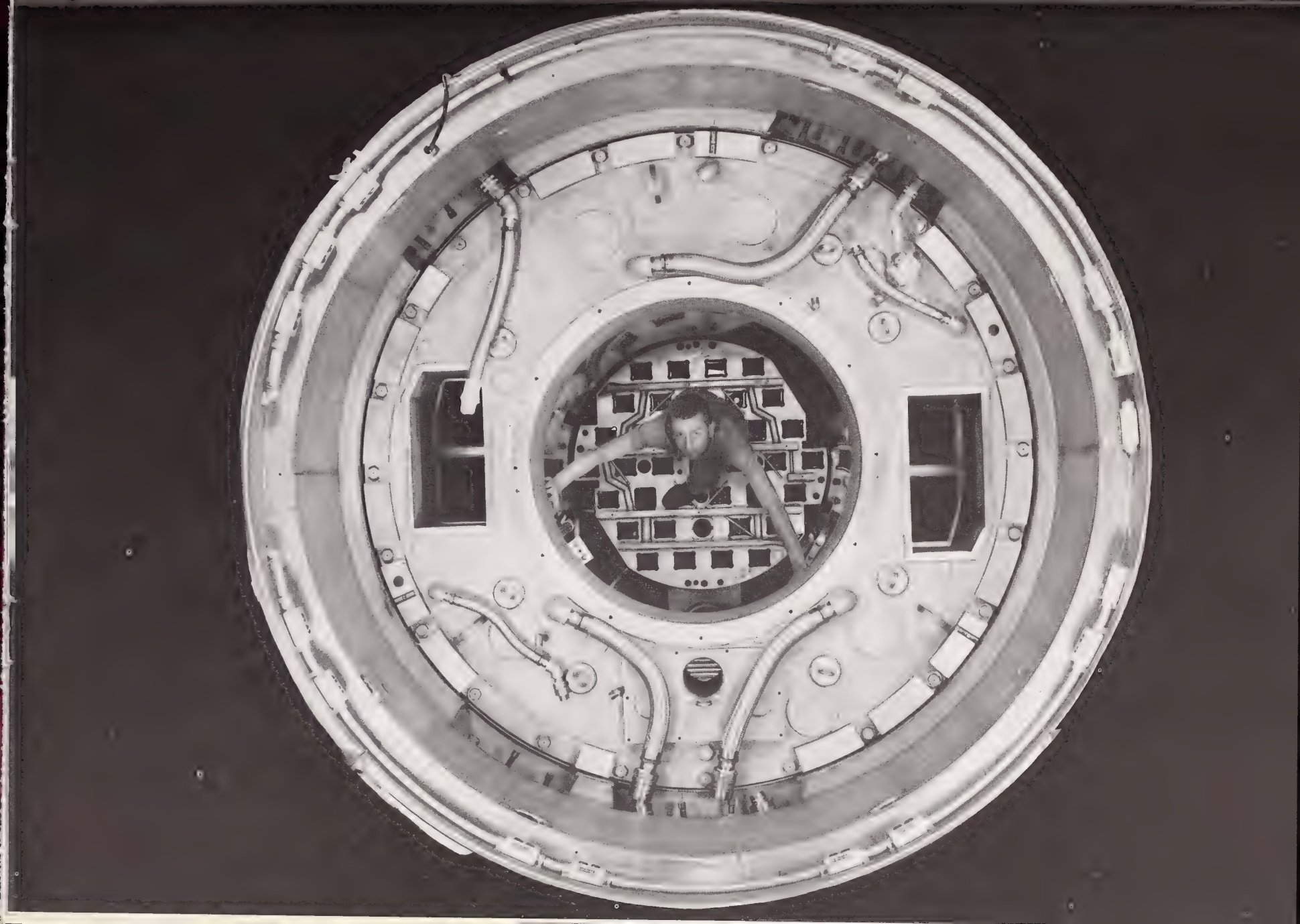
One example of a collaborative research program with a private organization is that of the NBS-American Dental Association joint Dental Research Program. The National Institute for Dental Research is also involved. This program, which has been in existence for more than 50 years, has resulted in many significant advances in both diagnostic and therapeutic dentistry.

These advances include two breakthroughs in dental instrumentation. The first was the development of a high-speed hydraulic dental drill which has helped to revolutionize dental practice by conserving the dentists' time and reducing patient discomfort. The second breakthrough was the development of a panoramic x-ray machine that produces an x-ray picture of the entire dental arch, with the supporting bone structure, on one large film, as opposed to the 18 separate pictures otherwise needed for a complete mouth examination. This machine reduces by a considerable factor the time required to x-ray a patient's mouth and also reduces his exposure to x-rays.

The Dental Research Program has also contributed extensively to our present understanding of tooth structure and the surface chemistry of teeth, and has made numerous contributions to the development of restorative materials (see Recent Highlights).

The second example involves the NBS Nuclear Reactor which currently is being used by many government agencies, universities, and national laboratories. Numerous important research programs are being carried out jointly with various organizations. Outside organizations include, among many others, the Picatinny Arsenal which is investigating the properties of explosive and metastable materials, the Naval Ordnance Laboratory which is studying the magnetic properties of materials, and the University of Maryland which uses the reactor facilities to broaden their programs in lattice dynamics and molecular spectroscopy. The U.S. Geological Survey uses the reactor to determine trace constituents in geological samples. The Food and Drug Administration is using it for a variety of studies such as the determination of mercury in common foods and total diets. Law enforcement agencies use it in their scientific criminal investigation work (see Recent Highlights). Pollution studies are being carried out at the reactor by the University of Maryland for the Atomic Energy Commission. In the past, radioactive fluorine-18 (F-18), an agent for bone lesion imaging, has been prepared at the reactor

NAS has many unique facilities. Shown here is the reactor vessel of the 10-megawatt, heavy-water research reactor.



for major Government and private medical centers in the Washington area.

These examples serve to illustrate the breadth of the service and cooperative programs that have been made possible by the development of a major reactor facility at the National Bureau of Standards.

RECENT HIGHLIGHTS

The word "material" has many different connotations. Materials Science and Materials Engineering are disciplines that are very broad in scope. Past advances made in Materials Science and Technology have contributed to the betterment of all aspects of human life including health, safety, and economic well-being. Thus it is understandable that there is a whole multitude of areas within the scope of Materials Science where various government agencies either have a primary responsibility or at least play an important role in conducting basic and applied research on materials and in the experimental development of new and improved materials.

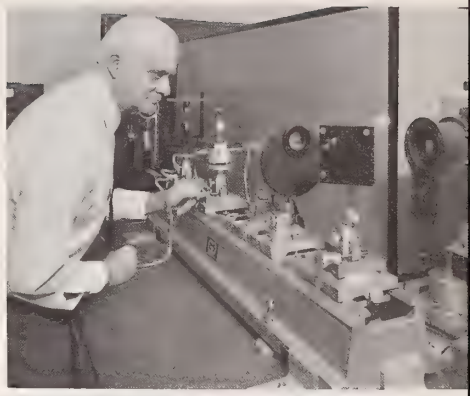
Within this broad context, the Institute for Materials Research has played a rather unique role, especially in the areas of materials standards, the development of improved measurement techniques, and the elucidation of concepts which explain the behavior of materials.

The following examples are a representative sampling of the many recent accomplishments of IMR:

Standard Reference Materials for Nuclear Energy

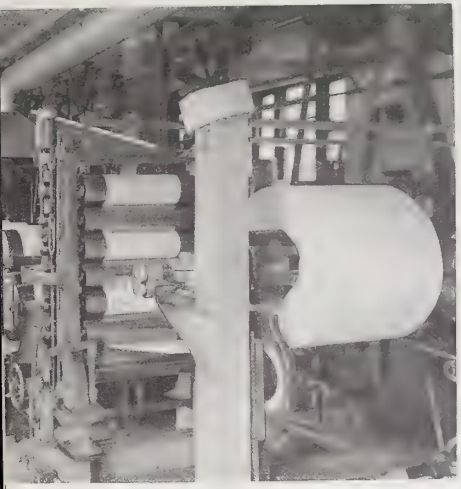
The National Bureau of Standards, in cooperation with the U. S. Atomic Energy Commission, has recently added a 99.975 percent pure Uranium Standard Reference Material (SRM) to its available list of NBS-SRM's for the chemical and isotopic assay of nuclear fuels. NBS now offers more than thirty different uranium and plutonium SRM's that were developed to meet the growing demands for national nuclear fuel standards. Nuclear power reactors are expected to come into increasing use over the next several decades in response to this nation's great need for additional power-generating capacity. Nuclear fuels comprised only 5 percent of the fuels used in 1970 or an equivalent of about 27 million tons of coal. It is estimated that the use of nuclear fuels will increase to about 55 percent of the market by 1990 or an equivalent of about 1,176 million tons of coal. The accountability of all nuclear fuels by the U. S. Government to private industry is assured by NBS-SRM's. These same SRM's also help provide for efficient, safe operation of nuclear power plants and nuclear fuel processing plants and, in addition, play a vital role in the U. S. Nuclear Safeguards Program.

This volcanic-like eruption on a lunar soil particle from the Apollo 12 mission was investigated with the scanning electron microscope (SEM). X-ray scanning with the SEM showed no metal on the surface. The particle was later cut and metallic inclusions were found inside, leading to the conclusion that the eruption was produced by stresses set up in the originally hot mass. These stresses resulted from differences in thermal conductivity of the included metal and the glossy host.



A highly accurate spectrophotometer has been developed by Dr. R. Mavrodineanu. The instrument has been used in the recent development of optically neutral glass and liquid filters that are available as Standard Reference Materials.

Concerns about mercury pollution aren't new. In 1931 Dr. W. T. Sweeney, through precise measurements, laid to rest fears that mercury in dental fillings might be poisonous.



At about the time of the first World War the Bureau established an experimental paper mill to study the effects of manufacturing conditions on the quality of the product. A descendant of this mill is still in operation at the Bureau.

A closely related group of radioactivity SRM's are provided by NBS for use in the control of possible environmental pollution by nuclear power plants.

Neutron Activation Analysis in Scientific Crime Detection

The value of neutron activation analysis in examining physical evidence in crimes is well documented. Recently, however, the advent of the NBS reactor has greatly facilitated the wide and extensive use of this unique and extraordinarily valuable method in the Washington area. On the average, more than 100 samples are received daily for irradiation and analysis at the reactor. Three major Federal agencies (the Federal Bureau of Investigation, the Treasury Department, and the U.S. Postal Service), as well as numerous state, local, and other law enforcement agencies, use the NBS reactor regularly for forensic analysis. Physical evidence examined includes almost everything involved in crimes ranging from gunshot residue and bomb fragments, paints, soil, and biological samples to poison cakes and candies and illicit spirits and narcotics. In addition to routine analysis of evidence, extensive research is being carried out by the various agencies to expand and extend neutron activation analysis in the forensic science field as well as to characterize and catalog the composition of numerous important items. The method has been accepted by the courts, and the record is full of cases where the method has successfully been used not only in the solution of complex crimes and the apprehension and conviction of criminals but also in exonerating innocent people.

Chemistry of the Stratosphere

The Physical Chemistry Division has undertaken a study of the chemistry of the stratosphere. This work is in support of the Climatic Impact Assessment Program (CIAP) of the Department of Transportation. The purpose of CIAP is to study the possible environmental impact of high-flying aircraft on the stratosphere. This is a topic of extreme national importance.

Photochemical processes control the composition of the stratosphere. They are responsible for formation of the ozone layer that filters out harmful ultraviolet radiation. Exhaust from high-flying aircraft will introduce small quantities of chemicals such as water, carbon dioxide, and the nitrogen oxides, that might react with ozone and change the ozone shield.

It is not known now to what extent, if any, fleets of high-flying aircraft will affect the stratosphere. But the answer to that question appears to be accessible (before the planes fly) through a series of laboratory experiments and tests in the stratosphere.

A task force of 10 IMR scientists in our Physical Chemistry Division is studying the chemical aspects of this problem to obtain reliable values for the rates at which possible chemical reactions will occur. The study has already led to recommendations to the Department of Transportation about the chemical systems which must be

investigated to fill gaps in existing knowledge. Experiments are currently underway at NBS to supply much of these vitally needed data.

High-Accuracy Spectrophotometry

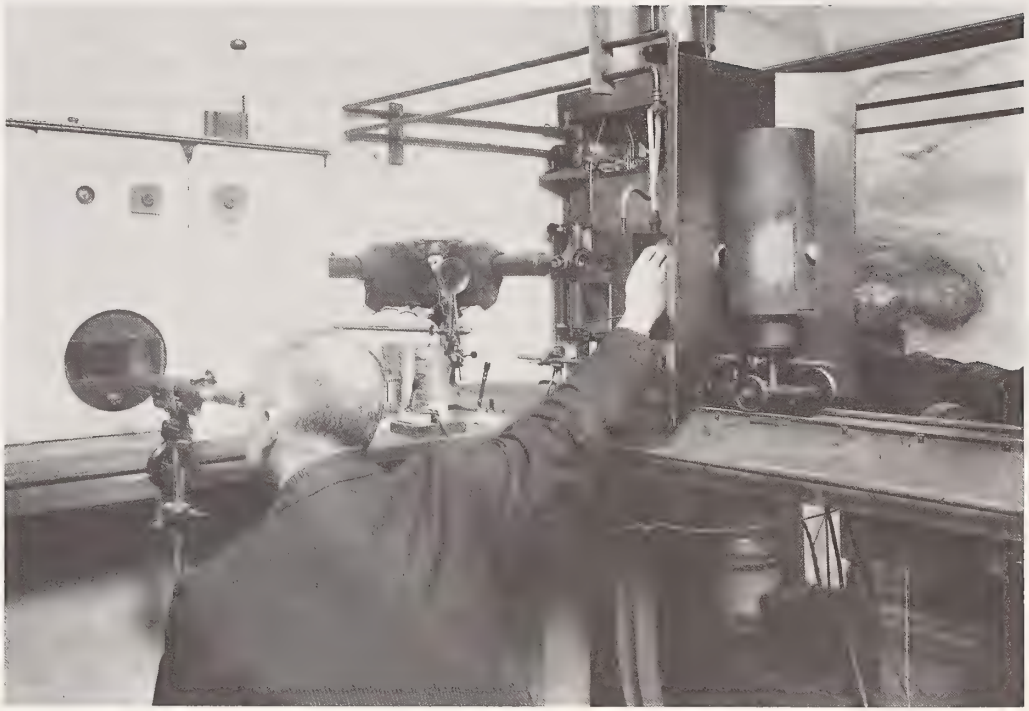
A spectrophotometer capable of measuring transmittance values on solid and liquid materials with an accuracy of 1×10^{-4} transmittance units was designed and built in the Analytical Chemistry Division.

The instrument measures radiant energy in the visible and ultraviolet regions of the spectrum and its accuracy is established by independent physical means. The wavelength accuracy and spectral bandpass are compatible with the photometric accuracy. Automatic operation, data acquisition, and presentation are provided through interfacing with a computer available in the Division.

The high-accuracy spectrophotometer is used to certify selected colored glass and liquid filters intended for checking the photometric scale of spectrophotometers in analytical laboratories. The use of these reference materials is important in clinical chemistry and environmental studies, which entail over 300,000 spectrophotometric measurements every day in this country alone. They provide the essential means to check the performance of a wide variety of spectrophotometers used for such measurements.

For that purpose Standard Reference Materials have been developed during the last year at NBS' Analytical Chemistry Division and consist of a set of three colored glass filters calibrated from 440 to 635 nm and a set of four liquid filters calibrated from 302 to 678 nm, and are contained in glass ampules. These filters, which can be used to check the photometric scale of spectrophotometers, are available from NBS as SRM 930 and SRM 931. Both SRM's were calibrated with the high-accuracy spectrophotometer.

A description of this instrument and of the SRM's 930 and 931 is given in the NBS Technical Notes 544 and 584.



In 1926 Dr. K. S. Gibson of the Colorimetry Section built the first spectrophotometers in which a photoelectric cell rather than the eye was used to make accurate determinations of color.

Dr. Alan Franklin with a buoyancy device for making density measurements on very small samples.

Chemistry of Flames and Flame Retardancy

As requirements for reducing the flammability of fabrics and other materials become more stringent, it is increasingly important to develop a detailed understanding of the mechanisms by which flame retardants operate at the molecular level. Knowledge of these essential chemical processes can permit more sophisticated design of retardants for particular applications and perhaps define the performance limits to be expected of particular retardant systems under service conditions.

A study of flame chemistry and gas-phase flame retardancy has been undertaken in the Inorganic Materials Division. In cooperation with the Bureau's Office of Fire Programs, a high pressure mass spectrometric sampling system has been developed for the direct analysis of flames and gaseous pyrolysis products. Designed to overcome several problems found in studying condensable or highly reactive intermediates at low or atmospheric pressures, the new system extends research on burning and flame inhibition phenomena over an exceptionally wide range of pressures, temperatures, and molecular weights. With this apparatus, it is possible to sample and measure chemical species of high reactivity, such as radicals, from small, well-defined regions of a flame and thus to obtain detailed information on the effects of flame retardant additives.

In one application, the mass spectrometric flame-probe technique was used to study the mechanism of flame retardants employing combinations of antimony oxide with organic halogen compounds. In this widely-used retardant system, the antimony compound greatly enhances the effectiveness of the halogen compounds in reducing polymer flammability. High temperature chemical measurements with the mass spectrometer indicated that the formation of gaseous antimony trichloride is a key step in the process. Studies of flames into which this compound was injected indicated a relatively complex chemistry in burning systems containing antimony additives and suggested several possible mechanisms for the synergistic function of antimony in flame retardancy.

The selection and use of flame retardants for practical applications has been largely empirical. Studies of the sort now being carried out at NBS should provide basic data to guide industry in the formulation of retardant combinations and suggest new and improved approaches to flame retardancy.

Studies of Stress Corrosion Susceptibility

During the last year, significant progress has been made in understanding the role of passive film growth kinetics and properties in stress corrosion susceptibility. This work was done by Dr. Jerome Kruger and Mr. John Ambrose of the Metallurgy Division.

Measurements of the rate of film repair after removal of a surface film have been improved in three major ways. First, the technique has been refined so that repassivation events (film repair) occurring during a period of 10 milliseconds can be

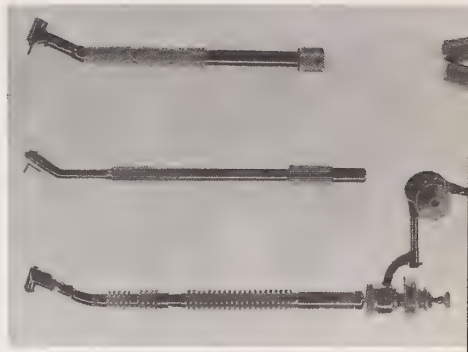
measured. Previously the speed of detection was of the order of 100 milliseconds. Secondly, the efficiency of film removal was markedly improved by the development of an abrasive pad that conforms to the specimen surface. Finally, the sensitivity of film thickness measurement was increased so that 3—5 Å (10^{-8} cm) films can be detected during a 5—10 millisecond time interval.

This newly refined technique, which has been given the name "tribo-ellipsometry," has been applied to studies of low carbon steel in nitrate and nitrite solutions at various temperatures. For these systems, tribo-ellipsometry has been able to separate the film repair process from the metal dissolution process that follows film removal. This was done by comparing the total current obtained from electrochemical measurements to the current calculated from film thickness measurements. By this approach, it was found that at elevated temperatures where low carbon steel is susceptible to stress corrosion cracking in nitrate but not in nitrite solutions, the current transients for both anions were not too different. However, the amount of current going into metal dissolution was greater for the nitrate. Thus, in the susceptible solution both the rate of repair and the ability of the repaired film to stop dissolution were less than that for the non-susceptible solution. Results of this sort can have great relevance in both predicting susceptibility and in achieving an understanding of the mechanism of stress corrosion.

Composite Dental Restorative Materials

One of the most dramatic developments in modern day dental research has been the development of direct-filling composite restorative materials. These are composed of an organic resin and inorganic reinforcing fillers. A cross-fertilization of expertise has been marshalled in the Polymers Division in an effort to meet the challenge of replacing silicate cements, an esthetically pleasing filling material but one that is mechanically weak and is prone to early chemical disintegration in the oral environment.

Experiments performed at NBS have provided the basis for private industry to produce seven new composite restoration materials that are now commercially available and are finding steadily increasing use in the dental profession. Latest estimates consider the composite materials to have replaced the use of silicate cements to an extent of about 50 percent. It is estimated that use of the longer lasting composite fillings could save the American public nearly a quarter of a million dollars per day.



The high-speed turbine drill now so familiar in every dentist's office is a direct descendent of the first hydraulic-turbine handpiece developed at NBS in 1953, shown here with a conventional handpiece.

CURRENT TRENDS AND FUTURE OPPORTUNITIES

This section presents possible future opportunities and potential program areas for IMR. Future programs and activities currently being considered by management are in the following areas:

- Failure Analysis and Avoidance
- Water Pollution Measurement Methods and Standard Reference Materials
- Materials for New Power Technology
- Standards for Synthetic Implant Materials
- Further Development of SRM Quality Control Systems

In several of these areas some preliminary work has already begun.

Failure Analysis and Avoidance

The consequences of a structural or materials failure can well be catastrophic. The collapse of a bridge or the crash of an airplane due to materials failure usually results in loss of life, extensive property damage, and great personal and economic hardship to the victims and others involved in the catastrophe. The problem to be faced is that of obtaining a fuller understanding of the causes of materials failures so that future disasters may be minimized. A Bureau-wide effort has been proposed that will focus the many talents of all three NBS Institutes into a program aimed at both the understanding of past failures of materials and structures and the prevention of future failures. IMR is expected to participate fully in this proposed program. The Institute already has a well-established Failure Analysis Program.

The IMR program will be aimed not only at analysis of actual failures but also at trying to more fully understand the causes of failures of materials in service by studying such phenomena as the wearing, degradation, and fracture of materials in order to prevent or minimize future disasters. The consumer should benefit by increased safety and performance of materials.

Water Pollution Measurement Methods and Standard Reference Materials

We hope to initiate a Water Pollution Measurement Methods and Standards Program in the near future. The primary goal of this proposed program is to provide the basis for reliable and compatible measurements of water pollution by the improvement of analytical methodology and by providing standard reference materials to ensure the accuracy of water pollution measurements. This will include the improvement of state-of-the-art detection and measurement techniques for radioactive water pollutants and the provision of appropriate standards to ensure adequate measurement accuracy. Another goal is the development of improved methodology for measurement of fluid flow.

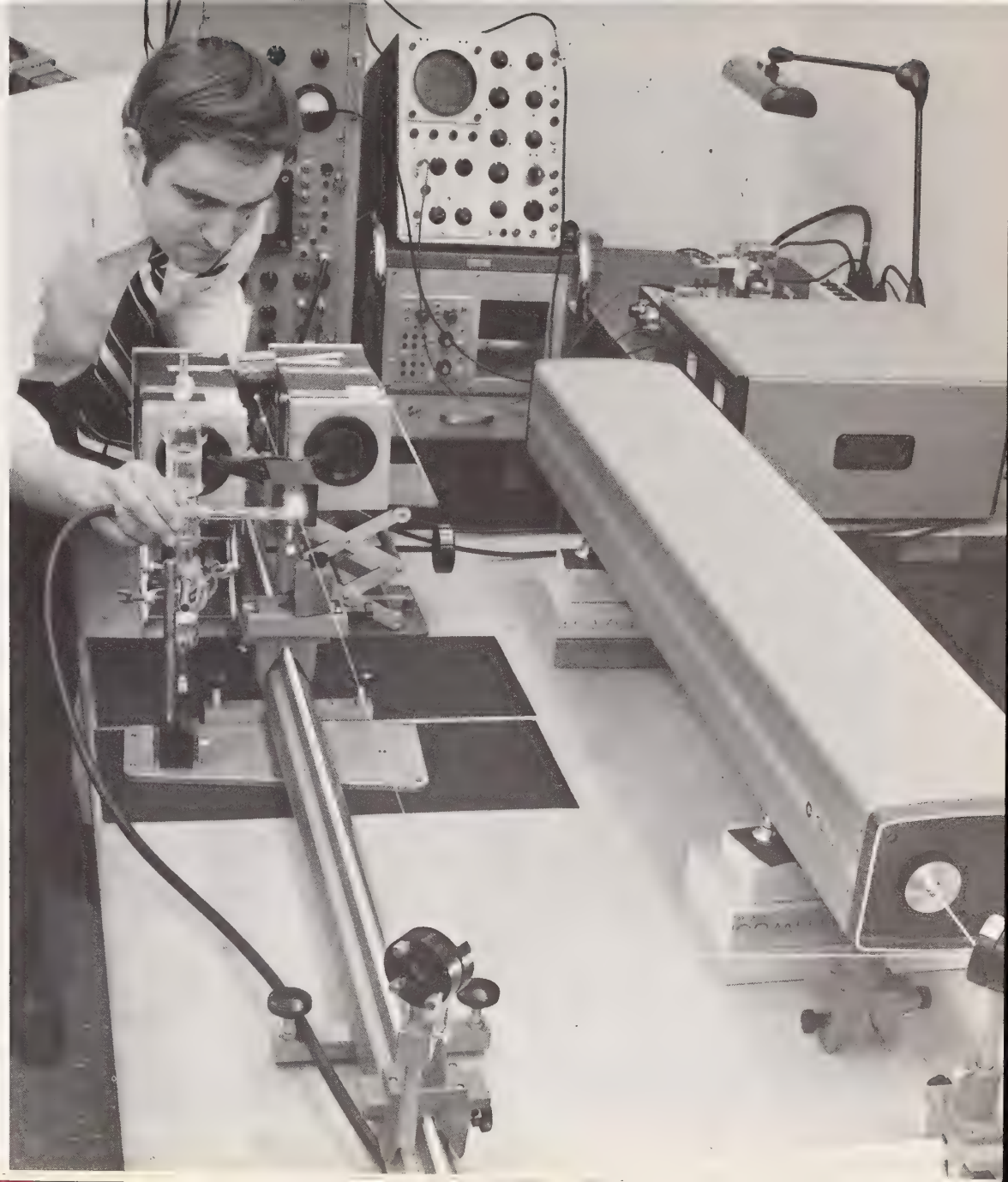
Recent experience has also emphasized the need for a better understanding of the fundamental nature of pollutants. Relatively innocuous substances can be transformed by natural or other processes to highly toxic forms, for example, the conversion of mercury to methyl mercury. But means to measure each chemical species as well as the basic understanding of the transformation process are often inadequate or lacking. A beginning is underway in IMR to study select problems in this area.

Materials for New Power Technology

The demand for energy in the U.S. economy is being only marginally satisfied as evidenced by summer electrical brownouts and blackouts in the eastern states and limitations on supplies of coal, natural gas, and low-sulfur fuel oil. The anticipated development of nuclear power has been recently restrained forcing continued reliance on fossil fuels, the sources and exploitation of which have not been developed sufficiently to meet future demands. Energy conservation must be instituted in part through improved efficiency of conventional power generators and development of new, efficient, pollution-free sources.

Efficiency improvements are limited by lack of information on high temperature chemical and mechanical properties of materials. If the efficiency of gas turbine generators can be increased from 30-38 percent by use of high-temperature materials such as silicon carbide or nitride, 26 percent more electrical energy can be obtained from a given amount of fuel.

Through its Materials Science and Technology Program, the Institute for Materials Research proposes to augment on-going and planned national research and development work on energy by providing critically needed fundamental data, measurement techniques, and standards. The major thrust of the proposed power



An instrument was recently developed by Dr. C. C. Gravatt ◗ that makes instantaneous measurements of the total number, size distribution, chemical composition, and non-spherical character of particulate matter in air.

program is directed toward problems related to the new forms of electric power generation and transmission methods. The development of these newer systems holds promise of furnishing electric power more efficiently than present methods, thereby conserving our natural resources and protecting the quality of the environment.

Standards for Synthetic Implant Materials

Another IMR opportunity is in the characterization of synthetic implant materials (biomaterials). Over the past 10 years, the medical profession has developed methods for prolonging life and mending major and minor body defects by simulation of the body organs with mechanical devices and replacement of its structural components with man-made materials. At the present time, approximately 40,000 electronic pacemakers, 45,000 artificial heart valves, 100,000 artificial arteries and 10,000 artificial hips have been installed. However, major materials problems associated with the use of synthetic materials in prosthetic devices and for implants in the human body still remain unsolved. These problems include the incompatibility of foreign materials with body substances such as blood and tissue, the degradation of the implant material in the body, and catastrophic failure or fracture of the implant. The IMR program under consideration is designed to help solve some of these problems by performing studies in such areas as: chemical analysis of implant materials; physical characterization of implant materials as to microstructure and surface characteristics; studies of degradation or deterioration of implant materials; and stress corrosion and fracture of implant materials. This program would be efficient only if done in an atmosphere of appropriate arrangements with other government agencies and with the advice of appropriate professional groups—the type of relationship that has proved successful in the Dental Materials Program.

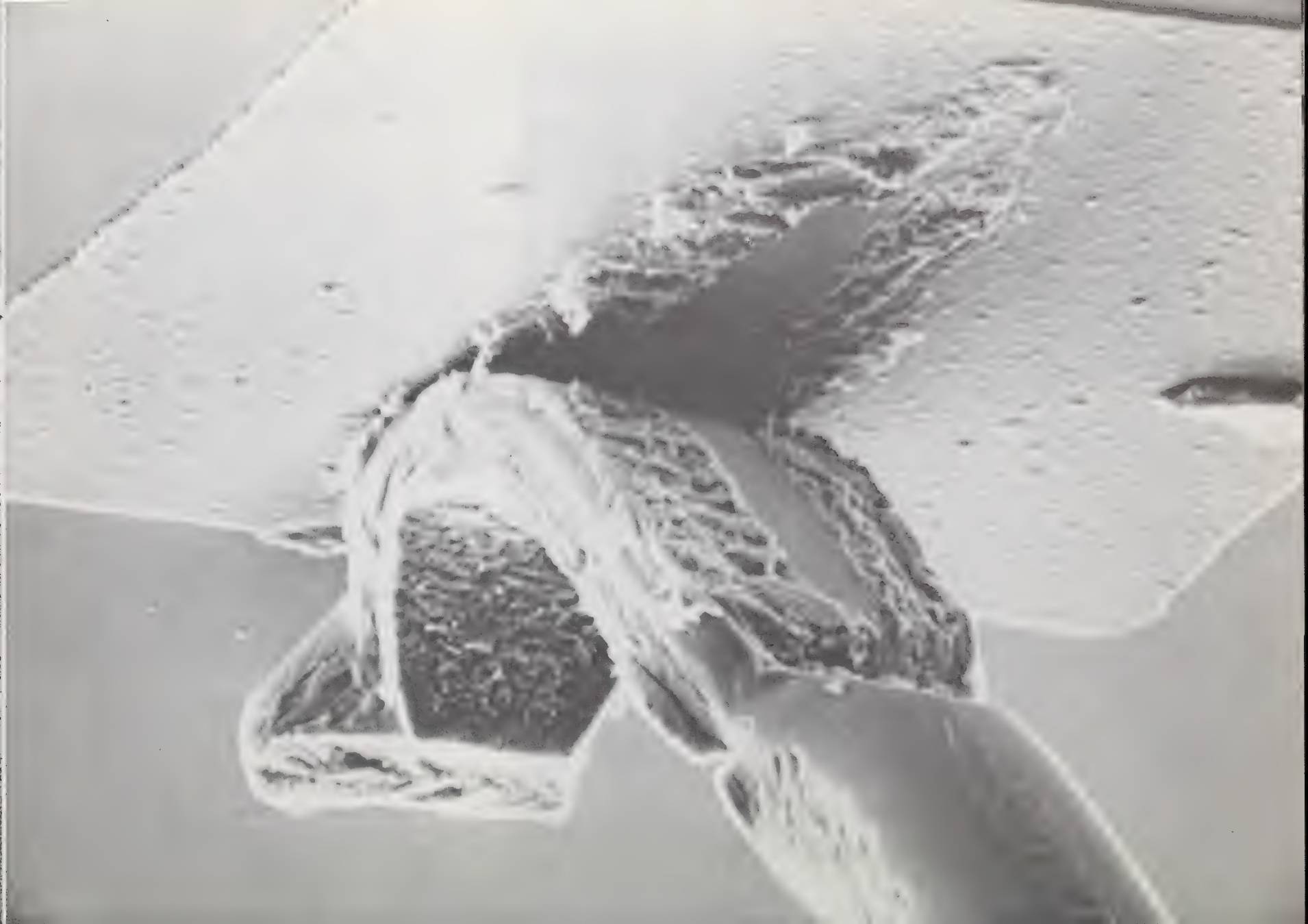
Further Development of SRM Quality Control Systems

For a method of measurement to be useful, it must possess three qualities: (a) precision-reproducibility; (b) accuracy—the correct answer or true value; and (c) specificity—measurement of the relevant property. To insure proper determination of these three factors when SRM's are used in industrial and commercial laboratories, NBS is introducing a quality control system for selected areas where the need is critical. The system consists of not only the development of SRM's but also the assurance of effective utilization of the SRM by providing adequate methods of test, data, and education to users of SRM's and the creation of an information feedback system usually in collaboration with other government agencies, professional societies, and trade associations to assure that laboratories maintain the requisite level of accuracy in measurement.

Work has already begun on a quality control system for clinical chemistry. For example, the first national authoritative

referee method of analysis (a method of known accuracy) in clinical analytical chemistry has been developed at NBS in cooperation with a team of experts from the clinical chemistry community and eight practicing clinical chemistry laboratories. This referee method is for the determination of calcium in serum, which is one of the most common of the nearly one billion clinical measurements made each year. Accurate determinations of calcium in serum are needed so that physicians can properly diagnose and treat such diseases as hyperparathyroidism and bone decalcification in patients. The referee method will now be used in collaboration with the Center for Disease Control of the Department of Health, Education, and Welfare, to assess the accuracy of the many different field methods for calcium analysis now in common use in the Nation's clinical laboratories. During the coming years, NBS will also begin the development of other important referee methods such as the determination of lead in blood (important for screening large numbers of children for lead poisoning, which can cause brain damage and death). The scope of this type of quality assurance program is also expected to be broadened into other areas besides clinical chemistry in the forthcoming years.

The laser is now being used by Dr. J. W. Hastie and A. B. Sessoms to study molecules in excited states. Here a laser beam is interacting with a stream of gas directed at the sampling cone of a mass spectrometer. The bright spot at the intersection represents the region of initial excitation.



INSTITUTE FOR APPLIED TECHNOLOGY

THE Institute for Applied Technology (IAT), as its name implies, is concerned primarily with applications of technology to human and social needs, although IAT's activities cover a wide part of the basic-to-applied spectrum which characterizes the overall NBS program. IAT was once described as "a collection of disparate activities." Yet there is a common theme which makes these activities part of a coherent effort: the activities are problem-oriented. IAT undertakes the solution of technical problems for its own programs and for a number of other agencies. Thus, IAT is in a position to—and does—contribute effectively to a number of problems of national significance and of great urgency. IAT's interests are in civilian technology, including in the term technology both hard (engineering and physical science) and soft (management and the behavioral sciences) aspects.

BUILDING RESEARCH

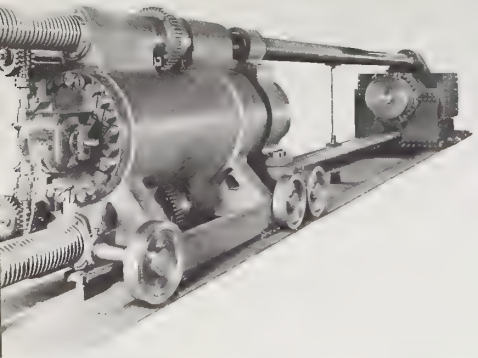
The NBS Center for Building Technology is taking on a new, more public service-oriented emphasis. During most of its half century in building research, the Bureau directed its attention to the development of technical data for engineers working on materials and structures for the building construction industry. The scope of research has now been broadened to include studies on the needs of building users. Research programs are being carried on in environmental, sociological, and psychological areas, as well as building fire research, systems engineering, building economics, materials, structures, and building information.

Another new emphasis is the development of performance-based building standards. The performance concept addresses itself to the specification of the functions that a building component has to perform and not to the specification of the specific materials or systems to perform this function. This approach to building specifications is opening the way for the use of innovative materials and processes.

IAT is playing a major role in Operation BREAKTHROUGH, a demonstration project of the Department of Housing and Urban Development (HUD) designed to increase the volume of factory-built production in the United States. HUD elected to rely on the NBS building research staff as its technical arm in housing technology. An interdisciplinary team developed the performance criteria for the evaluation of this housing and is managing the evaluation program itself which involves 21 industrialized housing systems.

In addition to working with HUD, NBS is cooperating with a number of other agencies including the National Science Foundation's Research Applied to National Needs (RANN) program. The research output of RANN's university-based program in earthquake engineering is being put into the appropriate form so that it is useful to

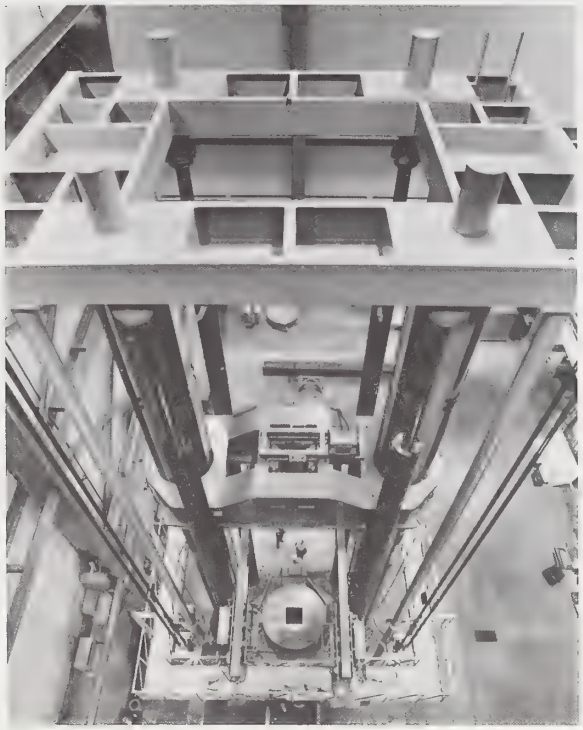
The scanning electron microscope is being used in an evaluation of the bond between wire leads and semiconductor surfaces. Here an area of good adhesion surrounds an unbonded area.



A machine capable of exerting up to 2,300,000 pounds in compression, was obtained in 1910 and used by the Bureau for many years in testing beams, girders, and other structural components. A new machine (right) which can apply 12 million pounds in compression, 6 million pounds in tension was dedicated in 1971.

building designers and building code officials. The university-based earthquake engineering program complements IAT's research program in structural design, and together these programs should produce results of value to the building construction community in seismically active areas.

The new Center for Building Technology replaces the former Building Research Division. The Center facilitates the fostering of major improvements in building technology; stimulates industrialization in building; disseminates information about building technology; and collaborates directly with industry, professional organizations, and other institutions in a joint effort to overcome obstacles to the introduction of innovative processes and materials into building technology.



FIRE RESEARCH

Leading fire experts in this country have made two major points:

1. The losses of life and property in the United States due to unwanted fires are very high. Among developed countries our death toll is three times the world average; our property losses are twice the world average.

2. This country is underinvesting in its R&D effort in this area. It is no coincidence that two countries whose per capita fire losses are substantially lower than ours, Japan and Great Britain, also have two of the best ongoing fire research programs. Both of these countries have well-equipped and well-staffed Government-supported fire research laboratories of top quality.

IAT is making substantial progress in the area of fire protection and safety. The three ongoing efforts have been combined into a single fire technology program. The three components are: the fire research effort in the building research program; the Office of Flammable Fabrics; and the activities under the Fire Research and Safety Act. These projects will retain their objectives of developing improved life-safety systems for buildings, the reduction of deaths and injuries due to fabric flammability, and the expansion of fire research knowledge plus

improvement of the technology available to the fire services.

One reason for combining the management of these projects is that they are all in need of a substantial research effort in such areas as the toxicity of the products of combustion, flame spread, fire-detection systems, and flame retardancy in fabrics.

Significant progress has been made in developing flammable fabric standards. As a result of NBS work, the United States now has the strictest standard in the world to protect children from burning sleepwear, and work is progressing on standards for blankets, mattresses, rugs, and carpeting.

Another spur to IAT efforts is the state of technology developments in the fire equipment field. It is technologically feasible for men with proper equipment to survive in toxic atmospheres. Yet, under hostile fire hazards, the breathing masks and bottles used by firemen only supply air up to 15 minutes on the average; the bottle weighs about 30 pounds and is so bulky that it is common practice for a firefighter to take off the mask and bottle as he climbs through the window of a burning building and have them handed to him when he is on the inside. While he is on the inside putting his mask back in operation his major source of protection is his turn-out coat. However, there is presently no flammability standard for the turn-out coats and some do not pass the flammability standard for children's sleepwear. The developing IAT fire program can be of direct help in improving this present lack of knowledge and outdated technology.

Secretary of Commerce Peter Peterson and his daughter demonstrate the effectiveness of a simple method for flameproofing fabrics.

Dr. Hugh Dryden (shown holding globe), aerodynamics expert, was asked by municipal authorities in 1928 to determine why so many street-light globes were blown away by high winds. One of the Bureau's wind tunnels is seen in the background.

OPERATIONS RESEARCH

NBS has the strongest and most diversified operations research capability in the civilian sector of the Federal Government. In the past several years, it has given convincing evidence of the great value of this activity to other Federal agencies and to State and local governmental agencies. This group brings together systems analysis techniques and the technical know-how of the various engineering and physical-science-oriented divisions of the Bureau.

The list of services performed is long and varied, including planning the allocation of resources for the Coast Guard's search and rescue activity; systems engineering and human factors studies of mail processing equipment for the Postal Services; the analysis of court reporting systems for the Department of Justice; analysis of airport runway capacities; key participation in the Northeast Corridor Transportation Project for the Department of Transportation; analysis of the proficiency of clinical laboratories; and the development of operations research packages, such as fire station locators, to be implemented by State and local governments.

PRODUCT SAFETY

The responsibility for product safety rests with the Department of Health, Education, and Welfare (HEW). NBS and the HEW Bureau of Product Safety operate a cooperative program whereby the IAT program in Product Evaluation Technology serves as the HEW technical arm. Particular emphasis is given to toy safety standards as mandated by the Toy Safety Act. Investigation of toys was conducted, for example, for the sharpness of points and edges, the burn hazards of electrical toys such as iron or stoves, hearing hazards from toy caps, and injury hazards from plastic "clacker-balls" that shatter in use. The findings were used by HEW in carrying out its responsibilities under the Toy Safety Act. However, other public benefits are anticipated. For example, the temperature burn-hazard findings on toys may be applied to household appliances in the development of standards aimed at eliminating burn hazards in the home. Similarly, the research findings on measuring hazards from sharpness of points or edges are applicable to many consumer products.

OTHER IAT PROGRAMS

Electronic Technology

The electronic technology group recently developed test methods which identified and eliminated faulty wire bonds—the largest cause of failure in transistors and integrated circuits. Application of their findings has resulted in a dramatically decreased rejection rate for components coming off the production lines. The plan now is to transfer some of the techniques for increased reliability developed for use by the military to civilian-related electronic equipment.

Engineering and Product Standards

The Engineering and Product Standards Division provides guidance and assistance to the engineering and product standards programs in IAT. It is the NBS point of contact on matters relating to the metric system of measurement, provides a library and reference service on engineering and product standards, and conducts the Department of Commerce's Voluntary Product Standards Program.

Weights and Measures

The task of the Office of Weights and Measures (OWM) is to make sure that the weights and measures activities of the 50 States are compatible. It is a job which requires both technical and diplomatic skills. The weights and measures officials of the States, counties, and municipalities have the regulatory authority and responsibility. OWM supplies these officials with technical information and provides training and a variety of other services. In support of the National Conference on Weights and Measures, an organization of State and local weights and measures officials which includes industrial organizations interested in quantitative measurements, model regulations are provided for adoption by the States.

This Office is effectively in the technology transfer business. The staff's job is to transfer the measurement science skills, which are under continuing development in NBS's Institute for Basic Standards, to State and local government officials thereby giving them the skills needed to facilitate trade and honest commercial transactions. It is an activity which antedates the formation of the NBS and yet it has a very contemporary flavor since it clearly acts as a protective service to the consumer as well as to the producer and distributor of goods. It is a simple but clear example of an NBS service of direct help to the public.

Law Enforcement Standards Laboratory

The latest addition to IAT is the Law Enforcement Standards Laboratory (LESL), established under terms of an NBS/National Institute of Law Enforcement and Criminal Justice (U.S. Department of Justice) agreement. The laboratory conducts research to develop national voluntary standards to assist law enforcement agencies in their selection and procurement of equipment. The laboratory will also develop methods for measuring the required performance of items in various categories including, among others, warning and safety devices for vehicles, communication devices, sensors for crime detection, protective equipment for personnel, and alarms. Altogether some 14 categories of equipment have been identified for which standards and performance measures are needed.

A standard for protective body armor, the first developed under this program, was recently released for use by the law enforcement community.

Invention and Innovation

The Office of Invention and Innovation provides specific services designed to help

For many years the Bureau was a leader in the field of photographing high-speed projectiles. This photograph was taken by P. P. Quayle in 1921.

A magnetic fluid clutch, operating on the principle that a magnetized fluid medium (such as iron particles in oil) can transmit torque between movable plates, was developed by Jacob Rabinow. This device has had widespread commercial application since its introduction in 1947.

the inventor bring his invention to the attention of potential manufacturers and investors. The Office works with State economic development departments interested in sponsoring Invention Expositions where inventors display their wares. The Office also sponsors the National Inventors Council composed of private citizens (outstanding inventors, both independent and those in corporation laboratories, industrial executives, educators, and patent lawyers) who advise the Secretary of Commerce with respect to policies affecting the processes of technological change. Over the years the Council has processed many inventions which have contributed greatly to the development of equipment used by the Federal government.

Consumer Information

Many IAT programs generate information of direct use by the consumer public, and recent efforts to make this information available have progressed significantly. A consumer guide series was started, and several widely distributed brochures have been published on tires, fabrics, adhesives, books, and other consumer-interest subjects. These brochures are distributed through sales at the Government Printing Office. IAT has also collaborated with the Office of the Special Assistant to the President for Consumer Affairs to inform homeowners of ways to achieve greater comfort, while at the same time conserving energy resources in heating and cooling buildings. This information is published in two brochures, 7 Ways to Reduce Fuel Consumption in Household Heating . . . Through Energy Conservation, and 11 Ways to Reduce Energy Consumption and Increase Comfort in Household Cooling, available through the Government Printing Office. Hundreds of thousands of these brochures have been distributed by electric utilities under the auspices of the Edison Electric Institute.

A carpet specimen that has failed a flammability test is examined by Dr. F. Karl Willenbrock, Director of the Institute for Applied Technology.

Measurement Engineering

To obtain a quick response to a technical problem, there is housed in IAT an NBS service group that serves the Bureau and other agencies as an engineering consultant in measurement technology. This group supports the research and calibration programs of the technical divisions of the Bureau. Its major staff competence is in electronics and in the combinations of electronics with mechanical, thermal, and optical techniques.

In an effort to reduce tragic accidents, NBS is seeking ways to make matches "childproof."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INSTITUTE FOR COMPUTER SCIENCES AND TECHNOLOGY

With more than 83,000 computers in the United States, the computer is a most pervasive element in American life. The NBS Institute for Computer Sciences and Technology has scientific and technical responsibilities for improving the efficiency and effectiveness of Automatic Data Processing (ADP) within the Federal Government and for providing leadership to Federal efforts to bring about the widespread application of computer and automation technology to increase productivity in the economy, improve the quality and availability of public services, and to enhance the competitiveness of U.S. goods in world trade.

The Institute's unique responsibilities and authorities stem from Public Law 89-306, enacted by the Congress in 1965 to improve the Federal management and utilization of computer technology. There are more than 6,000 computers in the Federal Government, making the Government the largest single user of computer technology. Under its congressional mandate, the Institute is responsible for providing scientific and technological advisory services to the central management agencies such as the Office of Management and Budget, the General Services Administration, the Office of Science and Technology, and the Office of Telecommunications Policy which formulate ADP management and procurement policies, as well as to other Federal agencies, assisting in the solutions of specific automation problems. The Institute is responsible for developing and recommending Federal Information Processing Standards (FIPS), participating in the development of voluntary ADP standards, and conducting research in computer sciences and technology including automation technology.

The constituency benefiting from the Institute's programs is made up of Federal computer customers and the customers for public computer services. The urgency of the Institute's program is underscored by the growing apprehension over undesired and unforeseen consequences of computer use, questions of right of privacy, for example, and the fact that computer and automation technology are not being used to their potential in solving the high priority problems confronting the United States. There is a growing recognition that many current national problems have as a core ingredient the need for better information collection and management—a characteristic of a service economy. The joining of computer technologies, communications technologies and automation technologies offers a solution to some of these problems.

The most pressing problems in the computer world are:

- Controlling accessibility to computer data banks in order to protect the individual's right to privacy;
- Methods for measuring the performance of computer systems and judging the quality of computer services;
- Quality control and productivity in the development of computer software, the schemata which makes possible the desired applications of any computer system;

SEAC—Standards Eastern Automatic Computer—the first general-purpose, internally sequenced electronic computer, was completed in 1950. Shown in front of SEAC is Samuel Alexander, who initiated the NBS computer group that evolved into the present Center for Computer Sciences and Technology.

- Marketplace standards;
- Techniques for effectively sharing computer equipment, software, and data banks;
- Effective applications of computer and automation technologies to enhance productivity.

The Institute's technical program is focused on developing solutions to these problems.

Controlled Accessibility

Concern over the appropriate and approved use of the growing amount of data generated about the American public and their right to privacy has stimulated the Institute's program on controlled accessibility. The problem has two facets:

- The technical problems of protection by use of hardware or software techniques;
- The social and legal aspects of privacy and the protection of property rights.

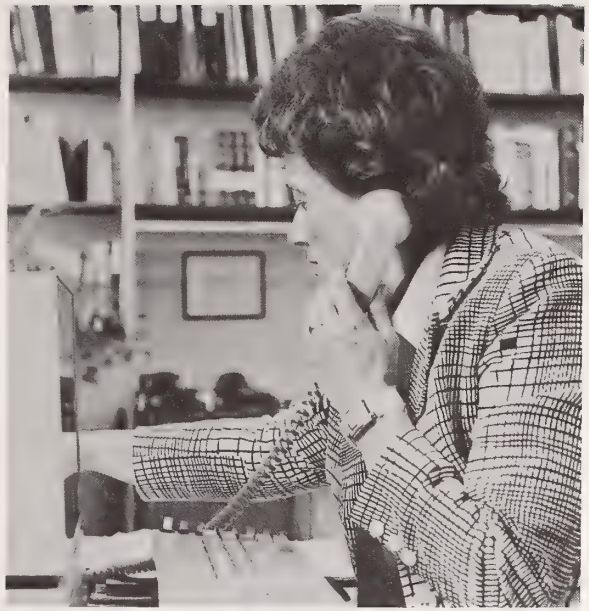
The technical aspects of the problem, while significant, are not insurmountable; their solution will require analysis of the social or legal problem.

The social or legal problem has two primary issues: the protection of individual privacy, and the protection of property rights. In the first case, the individual has misgivings about the accumulation of vast amounts of personal data about himself in an information system where the data are made available to users of the system. The uses of these data by properly motivated people could be of immense social value; however, the potential for abuse of the information by unscrupulous individuals is equally immense. In the case of protection of property, the problems involve not only the use of data, but the control of the data base and related software.

The Institute is encouraging innovation and research in the development of techniques, hardware and software, for controlling accessibility to computer data banks. The Institute is establishing mechanisms to effect a broad dissemination of this knowledge developed under Federal sponsorship. This effort is in concert with the Office of Management and Budget, the Office of Science and Technology, and the Department of Defense. At the same time, the Institute is serving as the focal point for Federal coupling with computer security research being undertaken by private industry.

Performance Measurement of Computer Systems

The computer, as a major item of capital investment, is unique among the equipment that organizations buy and use because there are no effective methods for measuring its performance or the quality of the services it provides. The computer industry has few meters or gages for measuring either computer hardware or software performance. After more than a quarter century, there are only about a half-dozen monitors that can provide data on how various components of the computer system are performing and the techniques



Dr. Ruth Davis, Director of the Center for Computer Science and Technology, using the computer terminal located in her office.

for applying these monitors are not well developed. Yet there are indications that improvements on the order of 25 percent can be achieved in computer utilization by changes made possible through the use of monitors. Grossly, this could mean a 25 percent decrease in the cost of computer services provided by a given installation.

The Institute for Computer Sciences and Technology is developing guidelines and techniques for the effective application of performance measurement devices for today's computers. The Institute has initiated and sponsored a FIPS Task Group on Performance Measurement. This group has involved Federal agencies in the effort to develop guidelines for hardware and software component evaluation, as well as measurement techniques and procedures to aid in selection and installation of computer systems and components. The Institute is working actively with the computer industry to bring about a productive government-industry coupling in the technology of performance measurement.

Under its teleprocessing program, the Institute has developed the initial version of a hardware/software device to aid in measuring the performance of teleprocessing systems and computer networks. The device monitors, records, and analyzes the "dialog" between a user at a remote terminal and an on-line computer system. It provides data about user behavior, computer system performance, and communications facility utilization. Four types of data are acquired: total time required and number of characters transmitted during user input; system delay time before beginning to respond to the user input; time required and number of characters transmitted during system output; and time until the user again starts transmitting characters to the computer system. The monitor time-tags each character and through a post-processor program prints the entire dialog and assists in analysis of the data.

The Terminal Environment Simulator is another device under development to aid in measuring the performance of computer networks. The simulator will permit controlled loading of the network to obtain specific operational data for analysis of its performance under varying conditions of loading.

One of the earliest measurement and calibration services in the computer field was developed by the Institute for use with magnetic recording media. In addition to providing magnetic tape calibration and reference services to the General Services Administration's Magnetic Surfaces Laboratory, industry and other measurement laboratories, the Institute is developing high precision systems and techniques for measuring the performance of disks and magnetic tape cassettes. The Institute is also preparing to commence measurement research in advanced computer storage media such as holographic, magnetic bubble, and microperforation memory devices.

Dr. Selden Stewart conducting experimentation via satellite with computers at a remote location.

A Federal ADP Simulation Institute became operational on July 1, 1972 under the terms of an interagency agreement between the General Services Administration and the Department of the Air Force. The Simulation Institute's mission is to provide technical assistance, support, and services throughout the Federal Government for simulation and performance evaluation of automatic data processing systems.

The Director of the Institute for Computer Sciences and Technology is a member of the Joint Policy Committee that provides overall policy for the management of the Simulation Institute. ICST is providing technical assistance in developing a proper perspective of simulation, as a single tool, in the overall computer acquisition process where several other techniques, such as benchmarking and validation, play an important role.

Software Management

Software (instructions which tell the computer how to operate) generally costs three to eight times as much as the computers themselves. Unfortunately, there is very little control over the quality of such software. Computer software is currently being produced by computer manufacturers, computer users, independent software

A program is underway to certify secondary standard reference digital tape cassettes (foreground). The apparatus on which Amory Ericson is preparing to calibrate an International Standard Magnetic Tape (sold by NBS as SRM 3200) will also be used to calibrate cassettes.

producers, research institutions, universities, and others. The customer's selection, utilization, and costing problems are compounded by the lack of software measuring techniques or product "guarantees" by the seller.

The Institute's software management efforts are focused in the areas of techniques for achieving quality control in the production of computer software, and on software validation services. Institute staff is working on the development of standard methodologies in the areas of structured programming, program testing and analysis, and program development. Efforts are also being made to develop standardized ways to document and describe computer programs to assist users in determining an existing program's applicability to their needs. These documentation standards will improve the effectiveness of computer services, broaden the capability to interchange and share software, and contribute to greater equity for buyer and seller in the computer marketplace.

The Institute is establishing validation services to assure the conformance of selected software to Federal ADP standards. The initial validation service encompasses the testing of COBOL compilers for compliance with Federal Standard COBOL (FIPS Pub 21) adopted July 1, 1972; a FORTRAN compiler validation service is also under development. The Navy Information Systems Division has developed tests for evaluating the performance of COBOL compilers; the Institute is defining the procedures to allow the Navy to test COBOL compilers on a Government-wide basis. The

Institute is also working with the Office of Management and Budget, General Services Administration, and the Department of Defense to establish the central COBOL validation service and relate it to the procurement/acquisition process. Centralized validation, as opposed to individual testing by each agency, will reduce the total number of tests required and provide a consistent interpretation of test results. Validation services will be available, on a cost reimbursable basis, to vendors and Federal agencies involved in a procurement or those wishing to verify a compiler already in use.

Test routines for validating FORTRAN compilers have been developed within the Institute. These routines were recently used to test compilers for the Department of Defense World-Wide Military Command and Control System. Initiation of a centralized FORTRAN validation service to be operated within the Institute is scheduled for 1973.

Sidney Geller positions a probe over a reel of magnetic computer tape to plot the field produced by the magnet at the left. This work is part of a study of the danger of accidental erasure of data encoded on the tape.

Standards Management

ADP standards are a useful mechanism for achieving compatibility or interchangeability of products, processes, services, or systems. As consensus-derived agreements on how the design/performance and other characteristics of products, processes, materials, services, procedures, conventions, and systems are to be described and measured, standards serve the purpose of making the customer independent of any single seller.

The computer industry is currently governed by de facto standards (i.e., standards which have come into use by general acceptance, custom or convention) rather than standards set by authoritative bodies. There are some 20 de facto standards in the area of peripheral interface equipment alone; similar situations exist in other areas of the computer industry, such as magnetic tape and disk storage characteristics, programming languages, media characteristics, word size in computers, and certain aspects of system architecture such as memory use and memory hierarchy. There are only 26 standards for the U.S. computer industry that have been adopted by the American National Standards Institute. In the Federal sector, 17 FIPS standards and two FIPS guidelines have been approved by the Office of Management and Budget and issued by the National Bureau of Standards. Some 20 FIPS standards are scheduled for completion over the next 2 years. Several other standards are in development for completion in later years.

Under Public Law 89-306, the Institute is responsible not only for the development of Federal ADP standards but also for ADP standards management. This means determining the impact of Federal standards policy and procedural decisions on Federal agencies and on the computer industry, developing and monitoring policies and procedures within the Federal standardization process, and developing a reporting procedure to provide information on the extent of standards implementation

and problems encountered in the conversion to standards. The Institute, in concert with the Office of Management and Budget, has put high priority on the development of a standards reporting system. The Institute is also stressing the determination of Federal agencies' compliance with FIPS. The initial effort is centered on FIPS 1, American Standard Code for Information Interchange.

The Institute has served as a catalyst in bringing about a significant new development in data communications standards. As an outgrowth of discussions between the Institute and the National Communications System (NCS) to establish an interface between the FIPS program and communications standards activities, the General Services Administration designated the Executive Agent, NCS, as the agent responsible for the development of telecommunications standards for NCS interoperability and computer-communications interface. This action clears the way for the Institute to work with the NCS as a focal point for computer-communications interface standards involving NCS facilities.

Computer Networking

Computer networking is the most advanced concept in computer resource sharing among communities of users. Although resource sharing among computer customers is increasing, it has not yet reached truly effective levels. The Institute's teleprocessing program is directed toward bringing about more widespread and cost-effective resource sharing through the combination of computer and communications technologies. The performance measurement activities of the program were described in the previous section on performance measurement. Other efforts include investigation of hierarchical computer systems configurations and centralization vs decentralization of teleprocessing systems.

In December 1971, the Institute installed a Terminal Interface Message Processor (TIP) and became a node on the Advanced Research Projects Agency's experimental network. Since that time, the TIP has been used to provide access to the ARPA net to Federal agencies in the Washington, D.C. area and to provide a mechanism for evaluating the network.

The Office of Telecommunications Policy (OTP), Executive Office of the President, asked the Institute in September 1971 to assume a distinct and special role in assisting OTP in carrying out its functions assigned by the President in the area of computers and communications. Specifically, the Institute was asked to provide technical advice and analysis in teleprocessing matters. The Institute has responded to several OTP requests for assistance.

Automation Technology

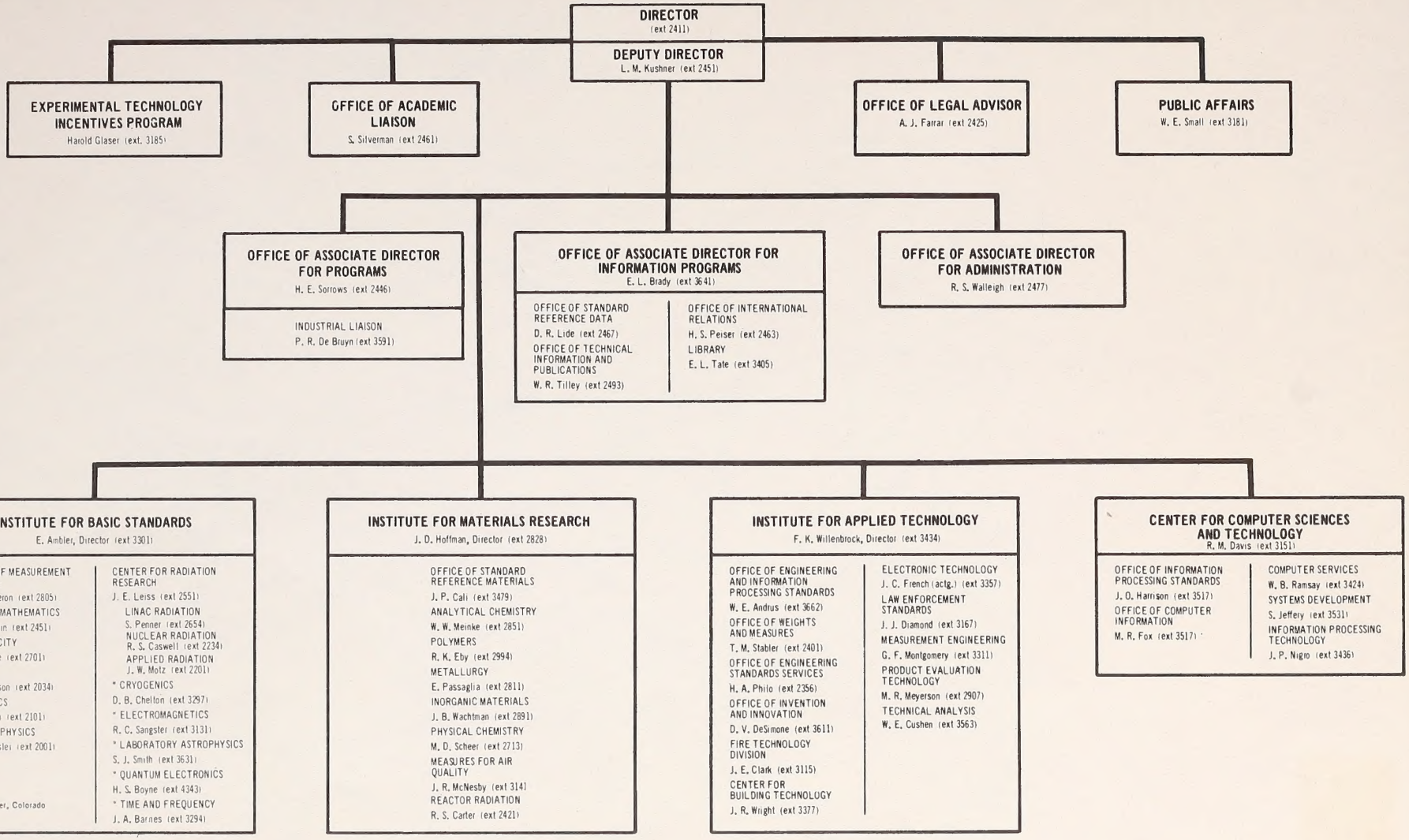
The Institute has initiated a new 5-year program aimed at applying automation technology to improve productivity in both the goods and services industries as well as to enhance the quality and competitiveness of U.S. products and services in world trade.

As a focal point for Government-wide efforts, the program's objectives are to apply automation to the quality control of essential public services; to improve safety in dangerous or hazardous occupations for public protection and safety; and to produce better quality products with better use of manpower. It includes cooperative efforts with industry and government groups to introduce automation into such areas as retail and wholesale merchandising, materials handling, and patient monitoring and diagnosis. The technical components of the program include: development and advancement of automation technologies; feasibility experiments and demonstrations of the products of automation technology such as a general purpose remote human-controlled manipulator of telefactor, automated electronic testing and diagnosis station, advanced interactive intelligent terminal, and a general purpose programmable robot; technology transfer through demonstration projects, an information center and training program; technology assessments to insure that social and economic impacts of automation technology can be integrated for maximum benefits to affected individuals and society as a whole; and management and coordination of automation technology among participating Federal agencies.

Other ICST Activity

The Institute is involved in a range of activities in the area of international computer technology. Through its Staff Assistant for International Computer Technology, it is conducting a collaborative effort with the Agency for International Development to survey selected less developed countries to assess their current utilization of computers and to formulate recommendations regarding U.S. policies for assisting the development of these countries through more effective use of computer technology. Other activities in the international area include: serving as the focal point for coordinating U.S. positions for international computer conferences and arranging U.S. representation; providing computer experts to serve as advisors to U.S. negotiators in trade talks; and providing technical assistance to the Department of Commerce Office of Export Control in assessing and updating policies governing the export of U.S. computers and related products.

Scientific and technical advisory services to other Federal agencies comprise a significant part of the Institute's overall activity. In the selection and acceptance of other agency projects, the Institute gives priority to those that make effective use of its unique competencies and which contribute to or benefit from the on-going computer technology program. Examples of major projects are ICST's technical assistance to the National Science Foundation in developing a methodology for the assessment of automated scientific and technical information systems, and in the planning and technical analysis of a National Science Computer Network for the university environment; and assistance to the Health Services and Mental Health Administration in the effective application of computers in health care services such as patient record handling.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